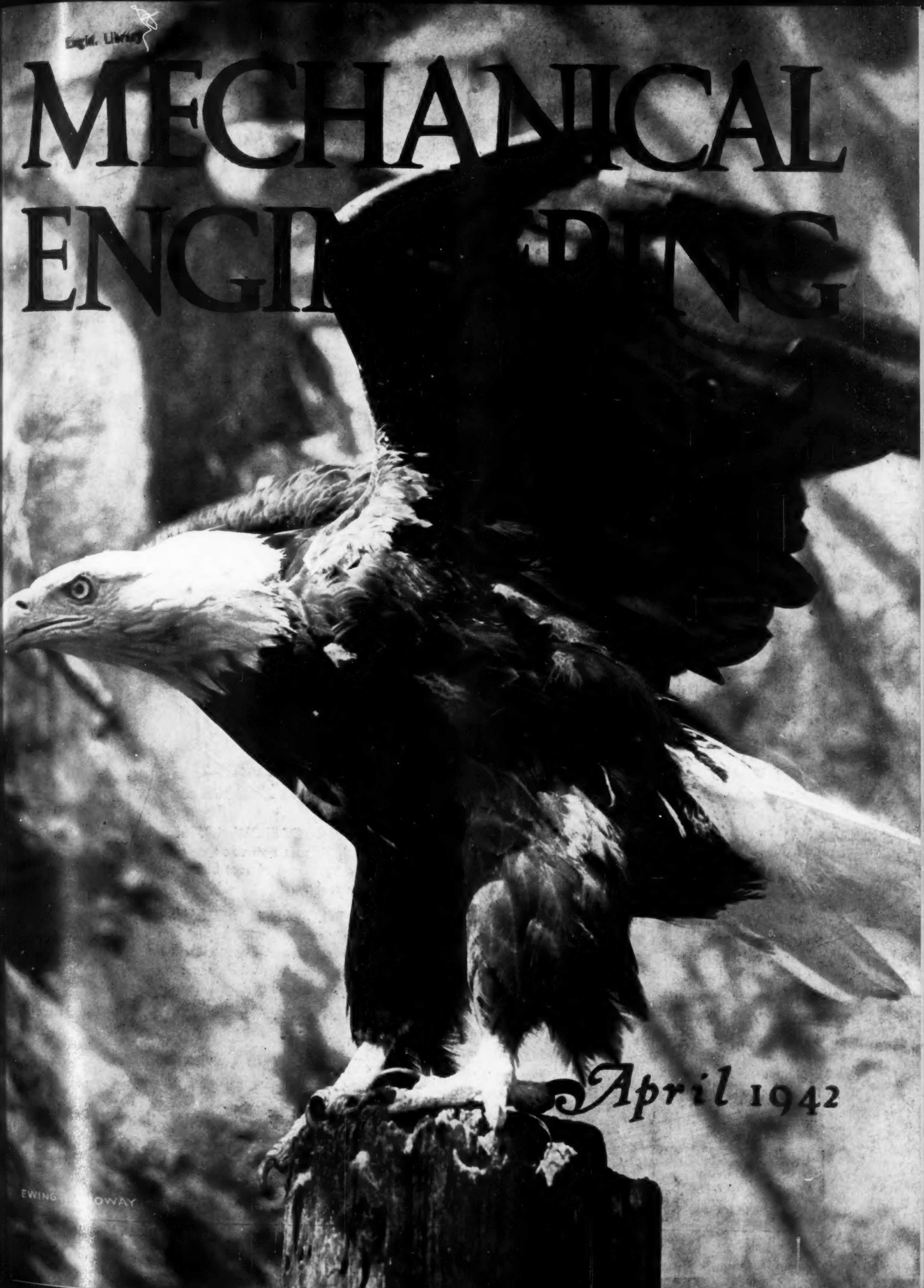
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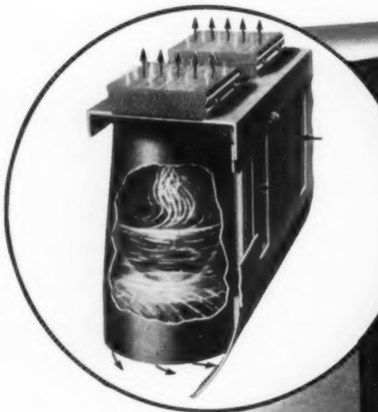

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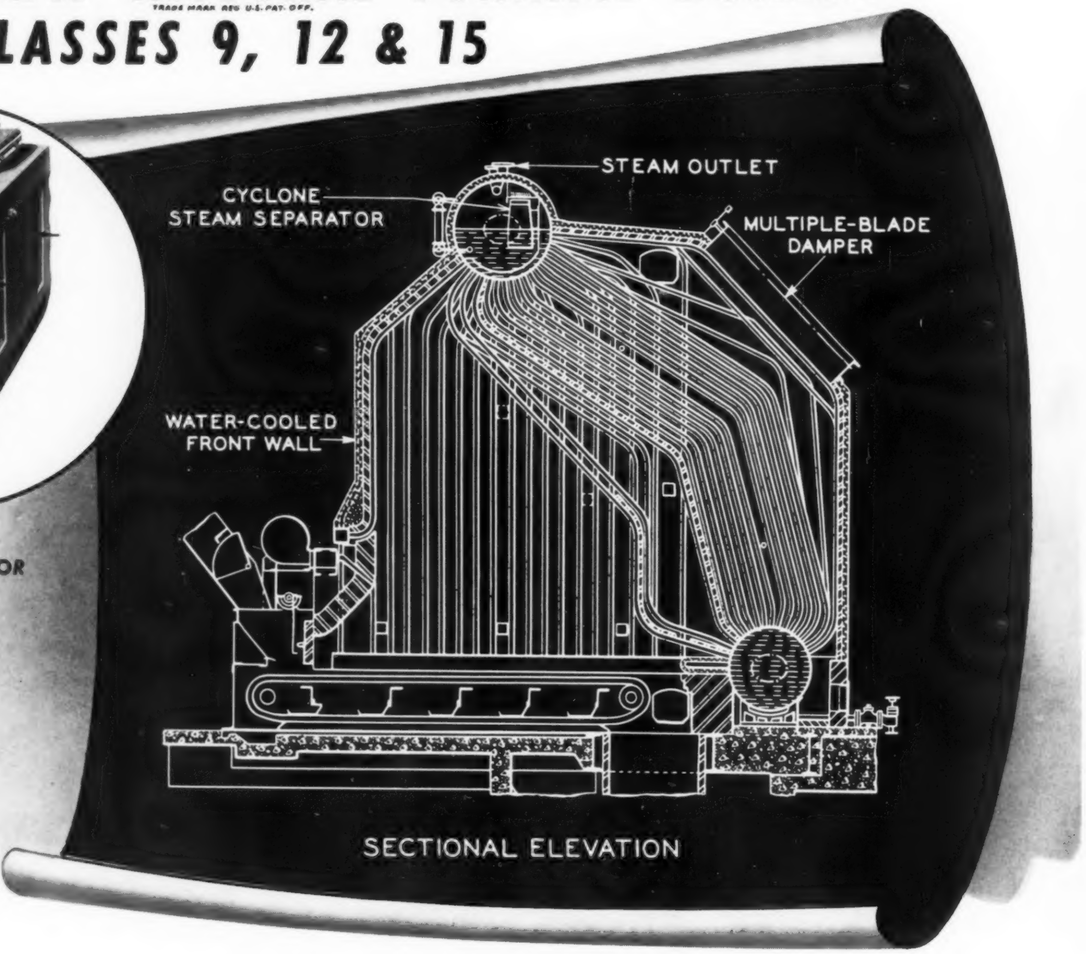

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Ewing Galloway

"Engineering Production for Victory"—Attaching a 90-Mm Antiaircraft Gun to Its Mount

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MECHANICAL ENGINEERING

April
1942

GEORGE A. STETSON, *Editor*

Engineering as a Career

ON this page last month attention was directed to a manual prepared and issued by the Engineers' Council for Professional Development to assist in the guidance of young men interested in the choice of engineering as a career. The manual affords a sound guidance procedure for the use of engineers and others who may have opportunity to assist young men in coming to an intelligent decision in choosing a career. As background material for the use of the young man, his teachers, and his parents in securing information on the engineering profession, another E.C.P.D. pamphlet, "Engineering as a Career," has recently been issued. The new pamphlet is a thoroughgoing revision of a former pamphlet, "Engineering—A Career, A Culture," originally prepared under the auspices of the Engineering Foundation and in recent years distributed by E.C.P.D.

"Engineering as a Career" is too matter-of-fact and unadorned to be propaganda in the popular meaning of that term. Its purpose "is to help the secondary-school student decide whether he will find in engineering the career which will enable him to use his abilities to his own greatest satisfaction and to the best advantage of society." It is not a "picture book;" it contains no illustrations. It is briefer than the pamphlet it supersedes—the text is confined to 32 book-size pages. Its three sections cover the scope of engineering, the principal branches of engineering, and a selected bibliography of "vocational-guidance literature." Repetition has been carefully avoided. It seeks to describe, not to glorify, engineering. Because of its condensed style, persons who wish to pursue the subject further, particularly those who wish to know more about the fields in which engineers are engaged, will have to turn to supplementary sources of information, such as those noted in the bibliography.

The day has passed when the world needs to be persuaded of the value of engineering. Conditions arising out of the war have given a particularly dramatic emphasis to the place engineering has made for itself in our industrialized economy. It is not engineering graduates who find their position insecure today or their talents and experience unessential. Nor are engineers likely to be thrust aside when peace comes. The same talents that have been called upon to convert a peacetime to a wartime economy will be required for the reconversion and the reconstruction to follow. Popular recognition of these facts will undoubtedly urge thousands of young men, who, under former circumstances, would never have considered engineering as a career, to attempt to find places for themselves in the profession. This imposes on the profession, for its own sake and for the larger benefit of society, the obligation to raise its standards, its qualifications, and its ideals of service and performance. Numbers may need to be increased, but by admitting only the best to the profession. This is the special concern of the engineering societies, of the engineering schools, of the engineering registration boards, of E.C.P.D., and of the pamphlet, "Engineering as a Career."

Salvage Begins at Home

THE desperate need for materials which the nation faces in order that the war effort may be speedily pushed through to a victorious conclusion has emphasized the importance of conservation and salvage. A "Clinic" on this subject was featured at the 1941 Annual Meeting of The American Society of Mechanical Engineers and initiated an expanding program of activities designed to drive home to every engineer the importance of keeping conservation and salvage constantly in mind. Notice of a suggestion sent to all A.S.M.E. Local Sections by the A.S.M.E. Management Division to the effect that they stage clinics in their own localities will be found on page 322 of this issue.

Another phase of the A.S.M.E. campaign has recently got under way in the setting up, at the instigation of the Engineers' Defense Board, of a Committee on Industrial Conservation headed by J. N. Landis, chairman of the A.S.M.E. Committee on Local Sections. Serving with Mr. Landis are Harold B. Bergen, Winchester G. Blake, F. D. Carvin, A. R. Mumford, and A. M. Perrin. The Committee has announced a three-point program in co-operation with the Industrial Salvage Section of the Bureau of Industrial Conservation, War Production Board. Its objective is to give wide publicity to conservation and salvage by publication of material relating to these subjects in Mechanical Engineering, by arranging for short speeches to be delivered at Society and local-section meetings, and by the distribution of information by mail through the courtesy of the War Production Board.

It is a well-known fact that many large industrial organizations long ago recognized the value of salvage and conservation and set up departments for the reclamation of waste. What is needed is to help smaller organizations establish their own programs and to offer suggestions and information to this end.

The plan of the Industrial Salvage Section, Bureau of Industrial Conservation, is simple. It involves the following action:

1 Put some one individual in charge of salvage in every operating, construction, and stores-handling department in your organization and give him authority to act.

2 Devise an effective method of bringing the message of conservation to all of your employees.

3 Build into your program a plan to keep it alive. Don't let initial enthusiasm die.

4 Act now.

Here is another way in which engineers in particular may contribute to the war effort.

Common Interests

THE common interests of engineers in this country and Great Britain are appropriately noted in an appreciative editorial that appears in the January 16 issue of *Engineering*. The inspiration for the editor's comments is credited to the award of the Worcester Reed Warner medal of The American Society of Mechanical Engineers to R. V. Southwell, professor of engineering science in the University of Oxford, and to the presidential address of Col. C. E. Davies, secretary A.S.M.E., to The Newcomen Society of England, "a typically British association which . . . . has acquired a status in the United States far beyond the wildest imaginings of the small group of engineers who founded it in London some 21 years ago." In the words of the editor, these are "two indications of American opinion and good will which are to be welcomed as evidences of that unity of mind and purpose among the English-speaking peoples which, at the present time, is the world's best assurance for the future of civilization." In the same editorial mention is also made of the addresses by Presidents Hanley and Parker at the 1941 A.S.M.E. Annual Meeting and their call for unity of engineering effort in winning the war and in preparing to face postwar problems.

What the writer of the *Engineering* editorial makes clear in his comment on Colonel Davies' Newcomen address is that this society, whose objects are "simply 'to encourage and foster the study of the history of engineering and industrial technology' . . . . has proved to be a potent influence in promoting a better mutual understanding between two peoples who, though springing from the same stock, might well have tended to drift farther and farther apart, in the absence of the urge to combine forces that is provided by German and Japanese aggression, were it not for the powerful centripetal effect produced by the possession of common interests such as these, into which there enters no suspicion of commercial rivalry or financial gain."

Since Colonel Davies' address was written, "German and Japanese aggression" has bound the members of the two nations together formally in a common cause, as well as common interests. To this statement it may be added that victory will extend common interests and a common cause to a common responsibility to the future. This responsibility does not arise from political considerations, for the pattern of political alliances is fluid and affected by numerous other factors as well. Indeed, the potency of common interests, which, as the term is here used, have led to a commmon cause and thence to a common responsibility, lies in the nonpolitical origin of those interests. They are found in all engineering and learned societies modeled after the form of The Newcomen Society of England, The American Society of Mechanical Engineers, and The Institution of Mechanical Engineers, to mention but three by name. They are also shared by many persons in the enemy nations, and by groups there that have been forced to accept political control. What makes nations of good will is a preponderance of men of good will who are willing to accept the responsibilities laid on them to make good will effective without sacrifice of decent demands of self-preservation and self-interest.

Just how these responsibilities are to be met is a question requiring the utmost patience, intelligence, wisdom, and effective action. They are faced not only by engineers but by all good citizens the world over. The fields in which engineers have competency as technicians have become important enough to warrant granting a larger authority to engineers as counselors and statesmen, provided they have the other qualities needed for such duties. Certain characteristics—objectivity, methods of analysis and performance, a basis of common interests untinged by political intrigue—are important assets, but must be exercised in larger and more difficult fields. Moreover, such engineers as may be elevated to these important posts must have the assurance that they have behind them a profession with high ideals of public need and public service.

Conversion

IN putting conversion into effect no time can be lost. The responsibility rests on individuals and on the plants managers to make themselves effective in the common war effort. Small public sympathy will be wasted on a plant which complains because its regular activities have been shut down because of restrictions on production for civilian consumption or because they are not "big enough" to be sought out for the execution of spectacularly large prime contracts. If access to raw materials or to normal markets has been shut off, no valid excuse can be made for failure to exercise initiative and energy in keeping every machine at work continuously on the manufacture of products that are desperately needed overnight. The enemy will not be beaten by finding alibis or by blaming conditions.

Conversion of productive capacity is a technical job that only those in responsible charge of plants can handle. What the nation needs is a quick and complete conversion of mental attitude on the part of every citizen from one of complacency, indifference, and wishful thinking into a determination to face the facts and get on with the job and see it through to its grim finish.

BEARINGS *and* LUBRICATION

Bearing Troubles Traceable to Design Can Be Avoided by Engineering Study

By R. J. S. PIGOTT

GULF RESEARCH AND DEVELOPMENT COMPANY, PITTSBURGH, PA.

In these days, the lubrication of certain classes of bearings, particularly those employed in heavy-duty, high-speed, internal-combustion engines and in automotive and aeronautic equipment generally, has become in many cases acutely troublesome. Apparently a good deal of this difficulty is due to the fact that the theory of the bearing has not been fully developed to practical application although the major basis of this work was Osborne Reynolds' theory, published in 1886; and even such theory as we have is receiving scant attention, especially among automotive designers. Observation has shown that a great deal of this trouble can be avoided by making some real use of what we already know about the operation of bearings. The theoretical treatments are now almost exclusively in the hands of mathematical physicists and are too much for the average engineer who has not mathematics enough to understand what these specialists write.

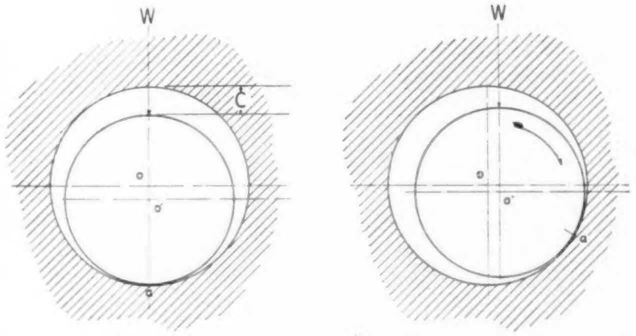

FIG. 1 (LEFT) DRY JOURNAL AT REST IN BEARING; (RIGHT) DRY JOURNAL DURING ROTATION

PRINCIPLES OF ORDINARY BEARING

A brief survey of the basic principles on which an ordinary bearing works may be illuminating. Fig. 1 shows the ordinary behavior of a bearing which has no lubricant in it. When at rest, it lies at the bottom of the sleeve with the center line of the shaft vertically under the center line of the shell. When rotation starts clockwise, the bearing tends, by way of friction at point a, to climb up the side of the shell. Such a characteristic can be seen on a lawn-mower front roller bearing, particularly as this bearing is not usually lubricated. The moment a lubricant is added to the bearing, however, the situation changes in a surprising way. Fig. 2 shows an unloaded lubricated, journal during rotation. This would be the case, say, of a grinder or a spindle transmitting only rotary motion, running at high speed. The journal tends to come very close to being centered in the shell with a film of liquid very nearly uniformly distributed all around it. This bearing, like any other, will develop heat, owing to the rapid shearing of the oil films over each other. Fig. 3 shows this condition. The velocity of the oil at the journal is the same as the surface of the journal since there is no slip between the oil and shaft. But the slip develops as we pass through the clearance space to the shell until by the time we reach the shell the oil is stationary and has no relative motion to the bearing shell. The work done and consequently the heat developed can be quite accurately computed and the formula takes the general form

$$W = C\,\mu a v^2/b$$

where W = work, ft-lb
μ = viscosity, ft-lb-sec units—Reyns
a = area of rubbing surfaces, sq ft
v = rubbing velocity of bearing, ft per sec
b = clearance, ft
C = a constant

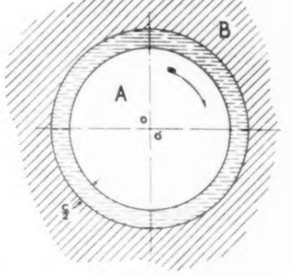

FIG. 2 UNLOADED LUBRICATED JOURNAL DURING ROTATION

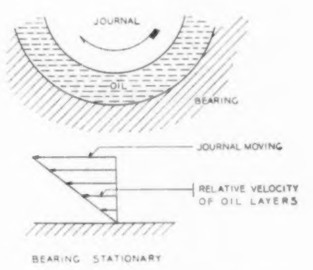

FIG. 3 SHEAR FORCES IN UNLOADED BEARING

As soon as material load is applied to the bearing, the condition becomes that shown in Fig. 4. This figure shows the conditions for a bearing of infinite length (which of course we do not have), and theoretically the center line of the shaft should move exactly at right angles to the line of the load, being 270 deg from the application of load in the direction of rotation. In actual bearings, however, we are always dealing with finite lengths, and in this case the displacement will lie between the 270-deg position and the 180-deg position, directly under the load. As a rule, in a normal bearing it lies at about 40 to 45 deg below the horizontal plane and approaches closer to the lower point of the shell as the bearing is shortened axially. It will be noticed that the shaft in this case, instead of moving to the right the way that a dry shaft would have done under the circumstances, moves to the left. The reason for this is that pressure is developed in the oil by a pumping action which is produced solely by the adhesion of the oil to the rotating shaft; oil is dragged under the bearing, forming what is known as the "Reynolds wedge," considered to exist from point A to point B. If the shaft were centered in the bearing, as in Fig. 2, no such wedge would be formed and no pressure could be developed to support load; this latter condition is therefore approximated only in high-speed bearings running very lightly loaded.

Presented at a meeting, New York, N. Y., Jan. 22, 1942, of the Petroleum Division of the Metropolitan Section, The American Society of Mechanical Engineers.

TYPES OF LUBRICATION

The divisions into which lubrication may be divided can conveniently be stated as follows:

1 Perfect film lubrication, sometimes termed "thick film" or "flood" lubrication, in which the space between the journal and the sleeve or box is completely filled with a liquid, and no

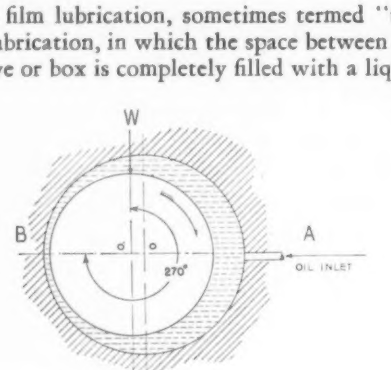

FIG. 4 LUBRICATED JOURNAL IN RUNNING POSITION

metallic contact whatever occurs between journal and sleeve when in motion, the journal floating on liquid film. This condition is indicated in Fig. 4.

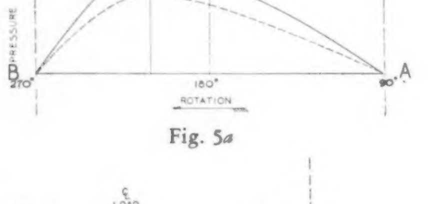

Fig. 5*a*

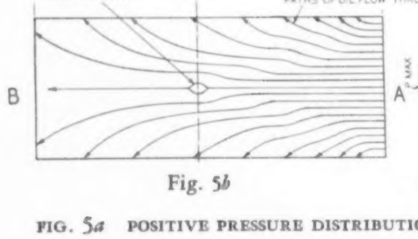

Fig. 5*b*

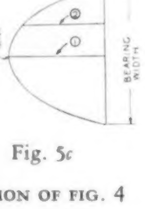

Fig. 5*c*

FIG. 5*a* POSITIVE PRESSURE DISTRIBUTION OF FIG. 4

FIG. 5*b* DEVELOPMENT OF LOWER HALF OF BEARING OF FIG. 4

FIG. 5*c* FILM PRESSURE DISTRIBUTION ACROSS BEARING (FIG. 5*a*)

2 "Imperfect film" or "boundary" lubrication, in which the load is so great, the speed is slow, or the viscosity of the lubricating liquid so low that the bearing moves over to touch at point *B* or some point lower and a limited metallic contact occurs.

3 Plastic lubrication, in which a grease or other semisolid replaces the liquid. Perfect films may be established but the usual cases where grease is used are likely to be in the imperfect film region.

THE REYNOLDS WEDGE

The reason a liquid film can "float" a loaded journal was first clearly shown by Prof. Osborne Reynolds in 1886 and his analysis was based on Beauchamp Tower's experimental data of 1883 and 1884. Petroff in 1883 had recognized the connection between viscosity and friction, but Reynolds gave us the underlying theory of liquid lubrication.

In order for a shaft to be floated on liquid, it is obvious that pressure must be developed in the film of liquid underneath the journal. Reynolds demonstrated mathematically that the only way in which a film can develop lateral pressure to support such a load is to assume a wedge shape, with motion from the broad to the narrow end of the wedge. Looking at Fig. 4, it is easy to perceive that oil must be fed in some manner, as for instance at groove *A*, in sufficient quantity to keep the lower half full; then as it is dragged around by the shaft, which acts as a kind of friction pump, and is compressed by the load on the shaft, it tends to squeeze out at the sides of the bearing. Fig. 5*a* shows pressure distribution around the shaft developed in the lower or loaded half, drawn along the center of the bearing. For an infinitely long bearing, this same pressure would exist completely across the width of the bearing, but we are concerned only with bearings of finite length. The effect of finite length is to drop off the pressure hump, shown in Fig. 5*a*, each way from the center line until the pressure is zero at the lateral edges where the oil leaks out. The pressure distribution across the width of the bearing at the region of maximum pressure is shown in Fig. 5*c*. It is seen that the pressure distribution in such a bearing is a kind of mound or hill in shape, reaching a peak somewhat beyond the direction of load and falling away to zero at the entering and leaving edges circumferentially and at both edges axially.

Theoretically, there would be a negative or suction pressure in the top half of the bearing equal in amount to the positive pressure in the lower half, but here the mathematical analysis fails to meet the facts for several reasons. The most important is that a negative pressure of only one atmosphere could be attained. Some slight vacuum does often occur; it is known that in "starved" bearings some air may be drawn in on the unloaded side. Such negative pressures as actually develop are too slight to affect the load capacity materially and in practical bearing design they are completely disregarded.

The approximate flow path of the lubricant when fed by groove at *A* is shown in Fig. 5*b*.

The important thing in designing a bearing is to determine the amount of eccentricity which will occur under given load per square inch of projected bearing area, rubbing speed, viscosity, and clearance. It is obvious that for a given set of these conditions, the load can be increased to a point where the eccentricity becomes so great that the shaft touches the shell. This condition starts to break down the film of liquid lubricant, metallic contact begins to occur, and the state becomes that of "imperfect film" or "boundary" lubrication. If the load is further increased so that general metallic contact occurs, complete rupture of the film takes place. Except for a few special cases where the materials are selected for the purpose and the rubbing speeds are very low, abrasion and seizure will generally result. Fig. 6 shows the actual pressure measurements of the pressure hump in a bearing, developed to show the plot.

Fig. 7 shows the action in a flat-type bearing, such as a Kingsbury or Michell thrust bearing, or such as may occur in the piston of an ordinary gasoline engine. The pressure hump develops in the same manner and leakages are of the same general type. Fig. 8 shows measured pressure distribution on such a shoe.

It is plain that the bearing structure and lubricant together must (1) support the journal in the bearing so that no metallic contact occurs and (2) remove any heat generated by shearing action of the lubricant or the displacement of the shaft from the center position, which also adds to the work of the bearing.

A little inspection will show that those portions of the bearing from horizontal to 45 deg below horizontal are of very little value in any case in supporting the load, since they have a very small vertical component of pressure and, for this reason, partial bearings such as half boxes or 120-deg boxes are often used and will carry about the same load under the same conditions

of speed, viscosity, and clearance as a full bearing. In fact, at high speed, the bearings will carry more, because the area of close clearances which generate heat in the oil by rapid shear is decreased and the heat generated is less, since the oil shear is reduced.

The mathematical theory as developed by Reynolds has never been reduced to a rigorous solution for a finite bearing until very recently. For many years the work of Kingsbury, Howarth, and Needs in graphical methods of solution had rendered Osborne Reynolds' theory available for design, but it is still insufficiently employed. Recently at the Gulf Laboratory, Drs. Muskat and Morgan have arrived at rigorous solutions of the mathematical theory to give the values for finite bearings such as are actually used.

THE CASE OF ACTUAL BEARINGS

Actual bearings depart from the simple assumptions for the Reynolds theory in several important particulars:

1 Bearings are never of infinite length, and in finite bearings the complicated flow path resulting from end leakage renders the mathematical solution correspondingly difficult.

2 The heat generation from oil shear and shaft displacement lowers the viscosity of the lubricant as it passes through the bearing and, again, not in a simple manner.

3 For many cases, the shaft and bearing housing together with the lubricant are the only means of heat removal, and this may be irregular with regard to the bearing surface. In most internal-combustion-engine crankshafts and many other cases, the bearing parts, such as connecting rods and crankcase webs, actually bring additional heat to the bearings from the combustion chamber, so that the only remaining source of cooling is the lubricant itself.

4 Many types of grooving and oil feed are employed. Every change of grooving from the simple assumptions made and shown in the foregoing figures causes a change in flow path and pressure distribution, and consequently a change in load capacity. We have almost no good test work on the effect of grooving on the load-carrying capacities, or the effect of increasing feed pressure. The general conclusion from such experiments carried out so far is that the load-carrying capacity can be raised by increasing feed pressure, but the amount is considerably dependent on location of feed, and the load-carrying capacity can also be raised or lowered by change of grooving.

5 Faulty alignment of shaft or bearing, or distortions under load, have a very pronounced effect on safe load and heat generated and cannot be analyzed directly. In the test machine, we may be able to develop, without any distress in the bearings, loads up to 3000 or 4000 psi, but in very few operations in which misalignments are taking place can any such figures be ordinarily attained.

THE FUNCTION AND EFFECT OF OIL

A bearing such as those described could be lubricated with a mixture of sugar and water, milk, or in fact any lubricant that has sufficient viscosity, but the reason we use oil is that it is almost the only commercial material obtainable in large quantities and at relatively low cost that will stay in the same condition unchanged chemically over long periods of time, even when considerably heated. Fig. 9 shows the effect of the character of the oil. Line *a* shows the bearing operated with sufficient cooling from some source so that all heat is removed as fast as it is generated and there is no change in the temperature of the oil passing through the bearing. Line *b* shows effect when an oil of high viscosity index is allowed to run through, with no other cooling. Reduction of viscosity going through the bearings reduces the pressure developed. Line *c* shows the effect when an oil of the same initial viscosity at room temperature, but lower viscosity index, is employed. This is an oil in which viscosity would reduce more rapidly with temperature than the oil used for line *b*. It is therefore plain that, if the oil is to be depended upon for removing heat, then the highest load-carrying capacities can be obtained in many cases by the use of

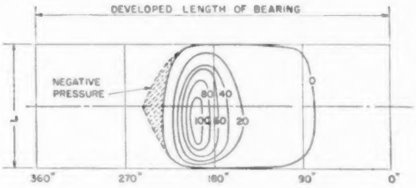

FIG. 6 DEVELOPED BEARING SURFACE SHOWING LINES OF EQUAL PRESSURE

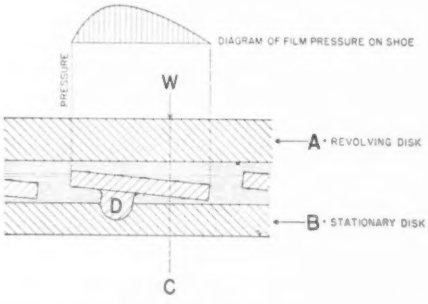

FIG. 7 PRINCIPLE OF KINGSBURY OR MICHELL THRUST BEARING

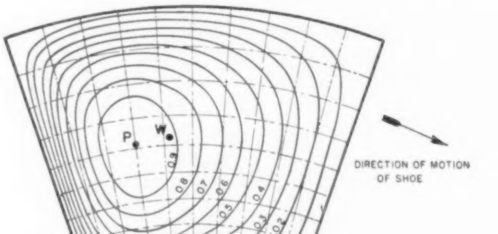

FIG. 8 PRESSURE DISTRIBUTION OVER THRUST SHOE

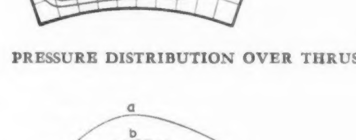

FIG. 9 FILM-PRESSURE DIAGRAM

oil of high viscosity index. However, if the bearing is cooled by other means, such as water jackets, then it is possible to take the cooling function away from the oil, and an oil of low viscosity index can be quite successfully used. There are other places in an internal-combustion engine where the differences in properties of these two kinds of oils have a bearing on which one is employed. It may be borne in mind that the viscosity of an oil of high viscosity index varies inversely about as the 2.5 power of Fahrenheit temperature; a low-viscosity-index oil, as the 3.0 power or more; water varies as about the first power.

EFFECT OF GROOVING

The effect of grooving has been discussed at length over a long period of years, but we have acquired very little test proof of

any arguments. One such case that has been investigated is the annular groove commonly employed for connecting-rod bearings in many automobile engines. This is shown in Fig. 10. It has often been stated by those thinking only in terms of the Reynolds theory that such a bearing should carry less load than before the annular groove is applied, the reason being that since the area is reduced and two additional leakage edges are afforded—that is, the bearing is converted into two of a little less than half the length each—the pressure hump should be reduced. Dotted line *a* at the right of the figure shows the ungrooved bearing pressure; dotted line *b*, that of the load-carrying capacity, supposing no change in viscosity occurs because of heating. But what actually happens is that when the annular groove is employed, the capacity for flow is more than doubled and may in many cases be tripled. This means that the reduction of viscosity for the same rate of viscous shear is much less because the temperature of the oil rises only one half or one third as much, and the net effect is generally an increase of load capacity which may go as high as 80 per cent for some cases. This has been proved by test.

The general opinion on grooving, as yet insufficiently supported by definite test, is that the oil supply should preferably be on the unloaded side near the thick end of the Reynolds wedge (*A-B*, Fig. 4), and should not be across the loaded area. While Fig. 10 appears to transgress these rules, as already explained, actually it does not. It merely converts the bearing into two shorter ones with full end feed. The advantage of this bearing is its ability to flow more oil than any other grooving and therefore to cool well.

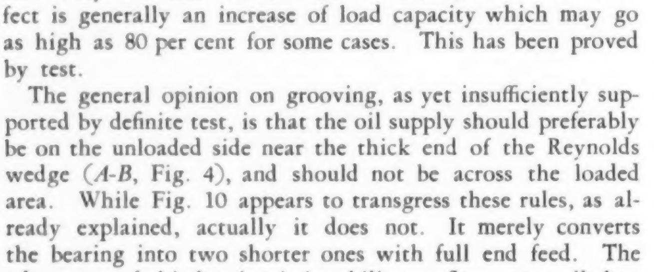

FIG. 10 CONDITIONS AFFECTED BY OIL GROOVE

In recent years, some bearings have been produced that have operated very successfully at extremely high bearing pressures—as high as 5000 psi. These are mostly confined to large bearings for rolling-mill necks; in this case the end leakage has been partially suppressed by means of packing devices at the edge of the bearings which in effect converts the bearing into something approximately like a bearing of infinite length. Moreover, in these bearings oil is flowed through so copiously that rise in temperature is only a few degrees. Also, the bearing is so set that the effects of misalignment and distortion are substantially wiped out.

To illustrate how important these effects can be, consider a rotary pump of a simple three-piece design, in which the bearing loads are quite high, which consists of a center housing and two end plates into which rigid bushings are pressed. It would take a week to bring this pump up to 600 psi using babbitt bearings, adding the load in small increments. If the pump were then dismantled and put together again, there would be sufficient change of alignment so that the conforming and wearing-in process would have to be completely repeated—that is, the only reason the bearing would carry the load at all is that the babbitt used would mush away or "conform" until it would assume a position in line with the shaft for whatever loads were occurring. Recently, application of bearings supported flexibly to follow the shaft freely resulted in the ability to bring the pump up to full pressure in 15 min with new bearings. Incidentally, this was done on water, and loads in excess of 470 psi were successfully carried with as poor a lubricant as water.

THEORIES OF FILM BREAKDOWN

Sommerfeld, in reducing the Reynolds expressions by definite integration, foreshadowed an operator—the product of viscosity and speed in revolutions divided by unit load per square inch—that is receiving considerable attention. Some years ago Hersey proposed the plot of friction coefficient against this operator and this plot has some quite useful properties, as shown in Fig. 11. This method of plotting, however, has also some limitations. The plots for different bearings do not coincide; the friction coefficient is a variable with change of oil, of bearing type and grooving, and with bearing surface condition and cooling means. Nevertheless, it has been considerably used by many engineers as a means of showing the point at which "boundary" lubrication is reached, that is, when the film tends to become unstable and the bearing approaches seizure.

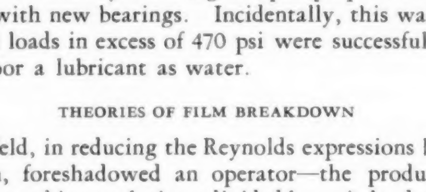

FIG. 11 RELATION BETWEEN COEFFICIENT OF FRICTION AND $\mu N/P$

(μ = mean absolute viscosity, centipoises; N = revolutions per minute; P = load on projected area, psi; f = coefficient of friction.)

The weak factor in this plot is that we are ordinarily unable to determine accurately the value of μ, the mean viscosity, and we have usually assumed that it corresponds to a mean temperature between inlet and outlet. This is very far from being true in many cases. In recent work at the Gulf Laboratory by Muskat and Morgan with a bearing in the best possible surface condition and the value of μ correctly determined by measurement, the test results follow the calculated curve toward zero for very much lower values of $\mu N/P$ than is usually taken as the critical point. A bearing in relatively rough surface condition may show some such curve as *a*, Fig. 11; when run in, lapped smooth, or otherwise reduced to very low roughness, with other conditions the same, the critical point will move down more or less like curve *b*. Or, by adding certain materials to the oil, generally known as "oiliness agents," the same shift can be obtained without altering the bearing surface.

In the perfect film region of lubrication, the only properties of the lubricant involved are viscosity and, of course, change of viscosity with temperature, but it has been known for a long time that certain materials could carry a bearing farther into the boundary-lubrication region without failure; that is, change would be, in Fig. 11, from *a* to *b*. This quality, christened "oiliness," is generally defined as that property in an oil which reduces the coefficient of friction at or near the boundary-lubrication condition. This is about all we can say about it because nobody knows how it works. Two theories are advanced for the action of oiliness agents. The first theory is that there is a selective adsorption on the surface of the metal, which consists chiefly of those constituents in the original oil

having oiliness properties. When the clearance, because of increased load, becomes sufficiently small so that these two adsorbed films meet, it is the same as if a more viscous lubricant, like a grease, were used, and the bearing will carry additional load. This theory appears to be contrary to some of the facts. If a lubricant of higher viscosity should thus appear, the friction coefficient should increase, instead of decrease, for an appreciable distance. The physicists hold that in any case this film can be only one molecule thick, and we can't make bearings that smooth.

The other theory is that another property of the oils used may account for the action. It is known that the viscosity of petroleum oils increases with pressure, and at high pressures the increase may be quite rapid. In general, however, the oiliness agents themselves, such as lard oil and stearic acid, tend toward increased viscosity rather rapidly with pressure and become solids at more moderate pressures. In a bearing approaching the boundary condition, roughness of the surfaces becomes important because the "hills and valleys" of the surface (actually only a fraction of a thousandth of an inch high) may be of the same value as minimum clearance, in which case the high spots on each surface tend to hit and break the film. At these points, which represent a very small percentage of the total surface, very high local pressures may occur. With an ordinary petroleum oil, increase of viscosity with pressure may not be sufficiently rapid to afford a material increase in load-carrying capacity, but any ingredients in the oil the viscosity of which increases sharply with pressure might convert it into a more viscous material or even grease-like solid which has flow resistance high enough to prevent film breakdown.

Since these local points have very small total area, the increased shear resulting from local increase in viscosity is too small to be detected and the friction factor continues to decrease with reduction of $\mu N/P$ to some lower value where, because of further reduction of minimum clearance, there are many more high spots ready to touch, local pressures become still more severe, and the little local grease spots can no longer furnish enough increase in viscosity to support the load. The bearing is then in the same condition as it was with the plain mineral oil with no oiliness agents present, and is ready for failure.

Both the foregoing theories lack proof. Kingsbury proved 20 years ago that down to a clearance of 0.000025 in. the bearing still follows the hydrodynamic theory. Later experiments have proved that this clearance can be as low as 0.00001 in. We have enough test data to show that some of the modern methods of bringing a finely finished bearing down to 3 to 7 microns does increase the load-carrying capacity quite noticeably.

Most of us believe from experience that the smoother the bearing, the higher the load capacity. Following another school of thought, one of the larger automobile companies is deliberately roughening the bearings to increase the load-carrying capacity and it is extremely curious that two such opposite ideas should persist in these times. What is probably happening in these roughened bearings is that conformability of the bearing to the normal distortions is increased. It is probable that the theory has been advanced from the known fact that piston rings with relatively rough-turned surfaces will seat more quickly than dead-smooth rings. One must remark, however, on the fact that people who are advocating roughening have presented absolutely no test data to prove that the bearing will actually carry more load.

USE OF BABBITT

In perfect film lubrication, the materials in the shaft and bearing shell appear to be of no importance whatever, but become important during periods of starting or stopping, or under heavy loads at low speed when borderline condition may occur. The widespread and successful use of babbitt metal is explained chiefly by the fact that it may partially fail without completely failing as a bearing, and in general it may fail without damaging the shaft. On the other hand the melting point of babbitt is relatively low and its strength decreases rapidly with temperature. Consequently, in internal-combustion engines, particularly where there has been insufficient oil flow over the bearing, temperatures have been brought up to such a point in the last few years that fatigue failures have been frequent. This situation has led to the use of other alloys such as cadmium silver, cadmium nickel, and copper lead. These materials have much higher strength to withstand the bearing temperatures now subsisting but have introduced many other troubles. Since these alloys are much harder and stronger than babbitt, conformability is much less and the danger of ruining the bearing during break-in is much higher as a rule. Furthermore, in general these alloys require larger clearances than babbitt and this may improve the situation by allowing a more copious oil flow over the bearings. The corrosion troubles with these alloys, particularly copper lead, have been so bad in the last two or three years that there is now a reversion to babbitt in another form. Steel backs covered with a coating of very moderate thickness of some intermediate material like copper nickel or powdered metal, and then with a thin skin of babbitt 0.005 to 0.008 in. thick for the bearing surface, allow the babbitt to carry as high loads as any of the copper-lead bearings, while retaining desirable conformability and other advantages characteristic of babbitt. Babbitt also eliminates the corrosion.

The author has felt for some time, and is now gathering considerable evidence in support of his belief, that the correct way to have cured troubles with babbitt bearings in internal-combustion engines was to improve the lubricating system and not necessarily change the alloy. He has found that the automotive engineers have paid very skillful attention to design of connecting rods, pistons, crankcases, and shafts for strength but have done almost no real designing of the lubricating system, which is just as susceptible to calculation within quite close accuracy as any other part of the engine. They are now beginning to realize that besides piston and steel shaft they have also a third material, oil, which must be treated as having breaking strength and as being capable of overloading just as metal is.

An illustration from one case used in proving the foregoing argument a year ago might be pertinent. Fig. 12 shows the connecting-rod bearing shell of a popular light car of some years ago that had very serious trouble with the main bearings in a small percentage of its output. These were usually confined to cases of long-distance hard driving, and a complete set of main bearings, including connecting rods, might be ruined after anywhere from 300 to 3000 miles of driving. The connecting-rod big end, Fig. 12, is lubricated in the usual way by means of supply through a hole in the shaft and an annular groove; but in addition it has a triangular groove, shown enlarged in the insert at the right, which has an astonishingly high oil-flow capacity. As a matter of fact, this groove actually flowed off from 90 to 93 per cent of the total oil fed to the bearing by the annulus, so that with a total supply to each connecting-rod bearing of around 0.65 to 0.75 gpm, the actual flow over the bearing surface, for both lubrication and cooling, was from 0.021 to 0.040 gpm, depending on speed and kind of oil employed. It was recommended to the designers that the triangular cross groove which was intended for removing dirt should either be cut out or reduced to a surface depression only a few thousandths of an inch in depth. The actual solution adopted by the designers was to cut out the an-

nular groove. In this case it was found that the supply pressure of oil reaching the connecting rod was automatically jumped about 15 to 20 per cent and the flow over the bearing was increased about 60 per cent, largely as a result of eliminating the triangular dirt groove. These bearings then were out of trouble.

But it does seem silly to supply $^1/_2$ gal of oil a minute to a

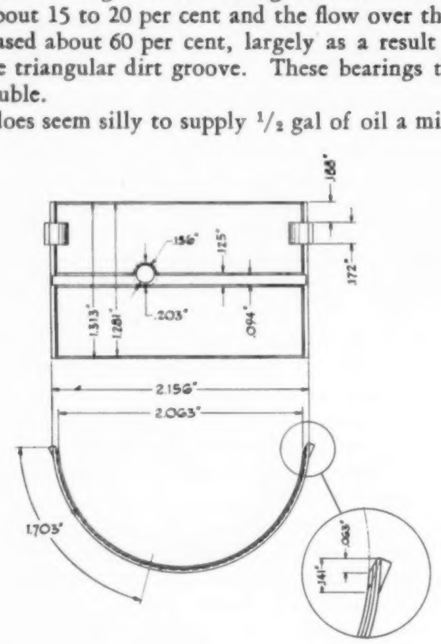

FIG. 12 CONNECTING-ROD BEARING OF A 1935 LIGHT EIGHT ENGINE

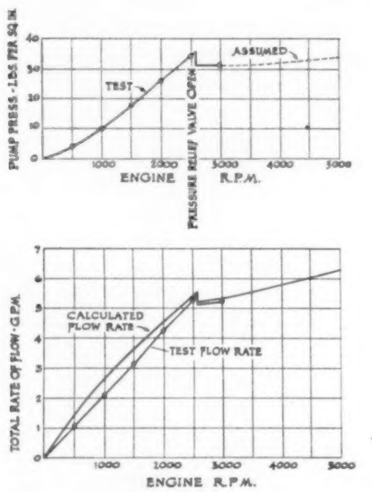

FIG. 13 COMPARISON BETWEEN TEST AND CALCULATED DATA

(*Top:* Pump pressure vs. engine rpm. *Bottom:* Total rate of flow through engine vs. engine rpm.)

(1935 light eight engine; S.A.E. 20 oil, viscosity index 105; ambient temperature 280 F.)

bearing and then use only 6 or 7 per cent of it for doing the job. This kind of error in design could very readily have been picked up before the car got on the market by doing a little calculating beforehand. To prove that so complex a problem as an 8-cylinder-engine lubrication system can be successfully computed, Fig. 13 shows the calculated and test results on the actual engine. In the low-pressure region where viscosity has its greatest effect on the computed flow and where variations in temperature of the bearings would alter the situation quite rapidly, the maximum error is not over 10 per cent, and in the region where the car ordinarily runs, the error is only 3 or 4 per cent. This is quite close enough to detect the difference between successful and unsuccessful bearings. Moreover, the method of calculation has been available for at least 40 years, if anybody had taken the trouble to use it; and it does not require any high-powered mathematics, although it is undoubtedly long and somewhat tedious. We are working now to see if we can devise some short cuts for analyzing engines in this manner to spot weak places in the lubricating system. This calculation has already been carried out on two popular cars and one high-speed Diesel engine and, it appears, will afford a valuable means of checking the lubricating design of any type of engine.

To illustrate further how bad the condition in this particular engine with the original grooving was, Fig. 14 shows that the temperatures of some of the bearings in this car were running as high as 400 F, and this situation was badly aggravated by the fact that the crankcase was running altogether too hot. The crankcase, which is still used in most gasoline engines for the entire cooling of the oil, is a very poor cooler. It is interesting to note that at the present time the car which was using cadmium-silver bearings when in trouble, has since returned to babbitt and has had no trouble from bearings for four or five years. In this case the whisper got around in the trade that the cheap oils, mostly of low viscosity index, would work in this car, and the high-priced, highly refined oils would not. The reason is simply that what was needed was greater flow over the bearings, and the viscosities of the oils of low viscosity

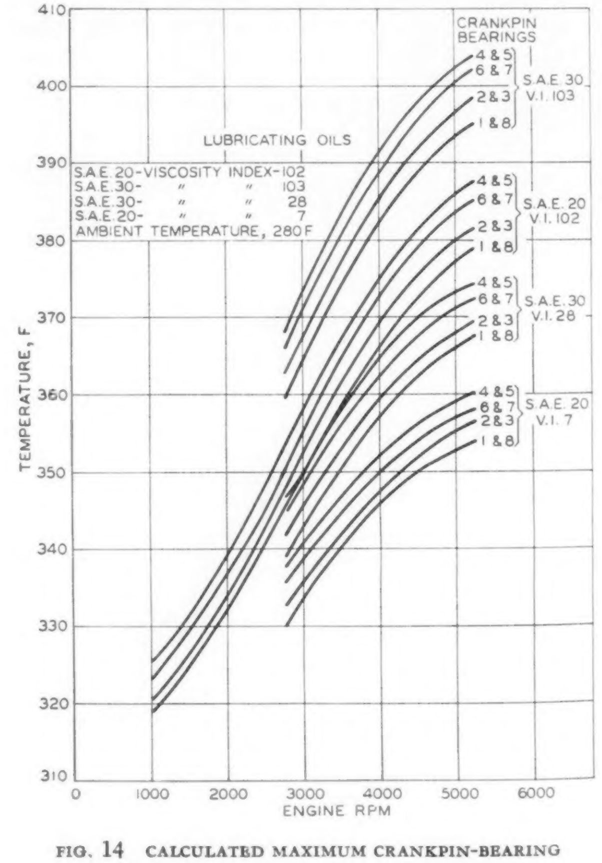

FIG. 14 CALCULATED MAXIMUM CRANKPIN-BEARING TEMPERATURES PLOTTED AGAINST ENGINE RPM

index were reduced by temperature effects much more than those of the high-viscosity-index oils so that about 30 or 40 per cent more oil flowed over the bearings. This greater flow was sufficient to eliminate bearing trouble.

Of course it must be observed that the engine did not require oil of higher viscosity to carry the loads, or the trouble could not have been cured by this means.

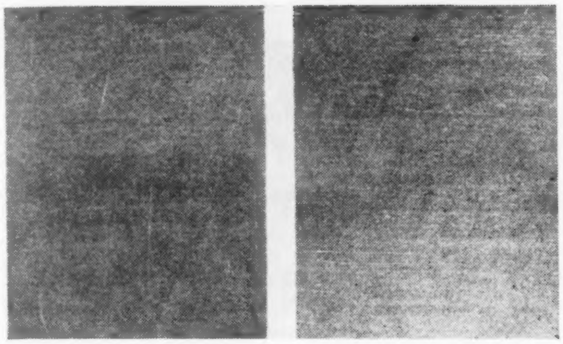

Fig. 15 is a section of a new copper-lead connecting-rod shell. (Note the smooth texture in comparison with that of the other figures. Also note that change in direction of lighting does not change appearance of surface.)

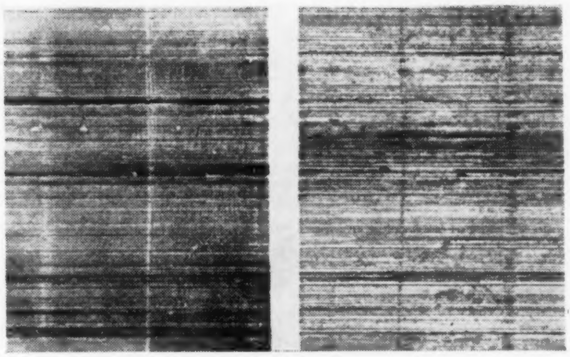

Fig. 17 is a section of a copper-lead bearing shell which formed the cap half of a connecting-rod bearing. Note severe scoring in figure on the left. With lighting direction changed by 90 deg in the figure on the right the scoring is brought out less sharply.

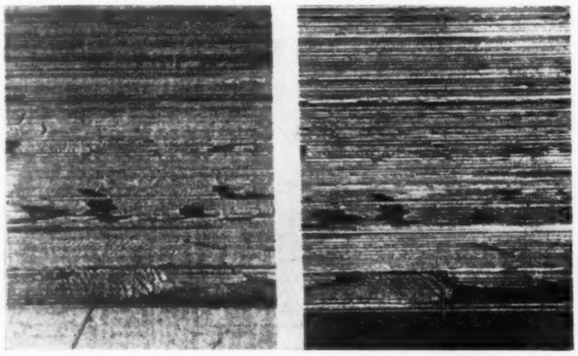

Fig. 16 is a section of a copper-lead bearing shell which formed the rod half of the bearing. Lead smeared over the surface of this bearing is indicated in the left figure by the light portions. The somewhat darker portions of the left figure represent smooth bearing surface. With lighting direction changed by 90 deg, the smooth bearing surface is lighter in color in the figure at the right.

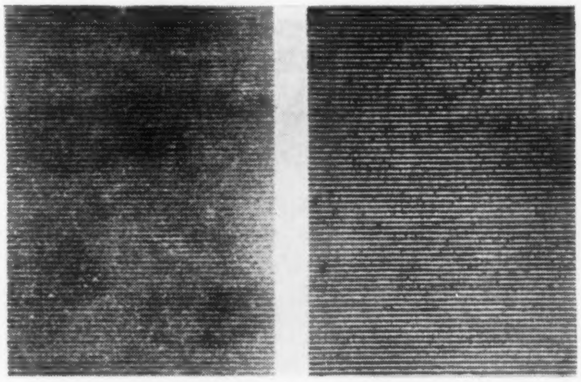

Fig. 18 is a section from a copper-lead connecting-rod-bearing shell which had been line-bored. In the figure at the right, note the ridges caused by the line-boring. The figure on the right shows the effect of changing the lighting direction by 90 deg. The ridges caused by line-boring are clearly seen and the tears along the ridges are brought out more sharply.

FIGS. 15, 16, 17, 18 SECTIONS OF COPPER-LEAD BEARING SHELLS

(In each case the lighting of the example at the right is at 90 deg to that of the one on the left.)

COOLING OF OIL NEGLECTED

Two designs of engine which are still on the market retain the old jet oil system. These, in hard service, show the same kind of troubles as in the example mentioned in the foregoing, and the bearings do not last long because of the very low flow over the bearing surface proper, and because the cooling which in this case is supplied largely to the exterior of the big end of the connecting rod is insufficient for good cooling.

In high-speed Diesel engines there is another problem which is mainly centered around the piston. Much more of the blow-by in a Diesel engine is air than it is exhaust gases. In fact, blow-by during the compression stroke is wholly air and probably 60 to 70 per cent of the blow-by on the explosion stroke is also air. Since Diesel pistons generally run hotter than gasoline-engine pistons, the oil is not only subjected to this higher temperature but also to an oxidizing atmosphere, and ring sticking is the major trouble. Naphthenic oils, which are of low viscosity index, have in general proved desirable for Diesel engines because on the hot piston they burn off clean and do not leave much in the way of gummy deposits and hard carbon; but in two-cycle engines, since the temperatures are still higher, the paraffinic oils have done better, although they still give some trouble. This is one place where so-called "compounded" oils have proved useful. An inhibitor against oxidation is added, and also in general a detergent—which means usually a metallic soap to wash the oxidized products, as they accumulate, down into the crankcase.

It is quite possible, as internal-combustion engines are designed for higher mean effective pressure and consequently higher horsepowers per cubic inch, that it will be necessary to adopt oil cooling of the piston generally to keep the temperatures low enough to avoid this kind of trouble. In only one high-speed Diesel at the present time is the piston cooled by oil, and this does not appear to be a good job because the oil is not being applied to the place that needs cooling the most.

EXAMPLES OF COPPER-LEAD BEARING SURFACES

The following figures indicate some of the conditions that are plainly evident in copper-lead bearings. Fig. 15 shows the uniform smooth condition of a new bearing as supplied by the manufacturer. This surface is smooth to 4 to 7 microinches roughness; so good that there is no change of appearance with 90 deg change in lighting. Fig. 16 is a section from a connecting-rod bearing, rod side, used in a light car. Lead is wiped over the surface. With lighting at 90 deg, the smooth bearing areas are dark in one case and light in the other. Some corrosion and scoring from dirt are evident. The bearing is ready for replacement but it has not failed. Fig. 17 shows the cap side where there is severe scoring. Fig. 18 shows a line-bored shell with a roughness of 200 microinches.

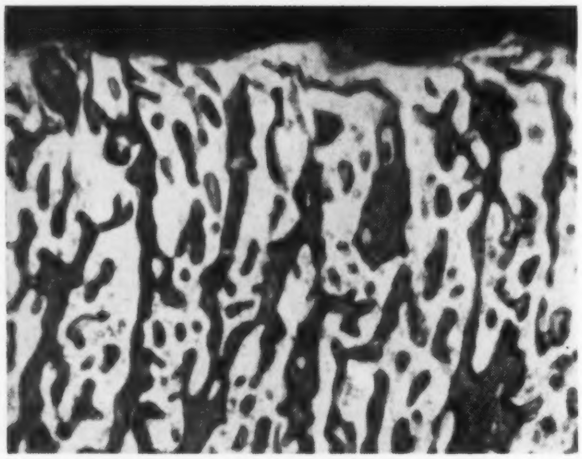

FIG. 19 NEW COPPER-LEAD BEARING, IN WHICH THE GRAY LEAD SHOWS UNIFORMLY, ×500

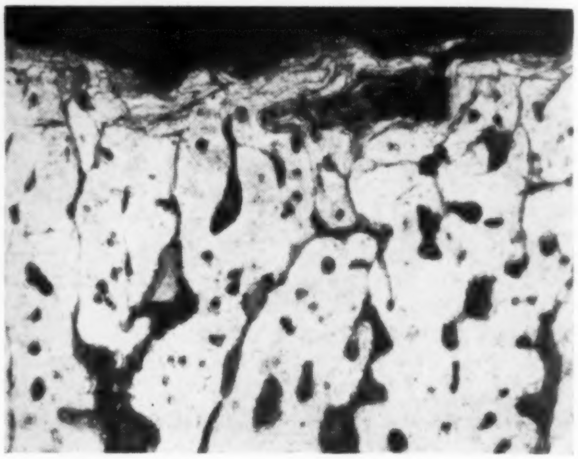

FIG. 20 COPPER-LEAD BEARING SHOWING LOSS OF LEAD SWEATED OUT OF SURFACE AND COMPACTING OF COPPER MATRIX, ×500

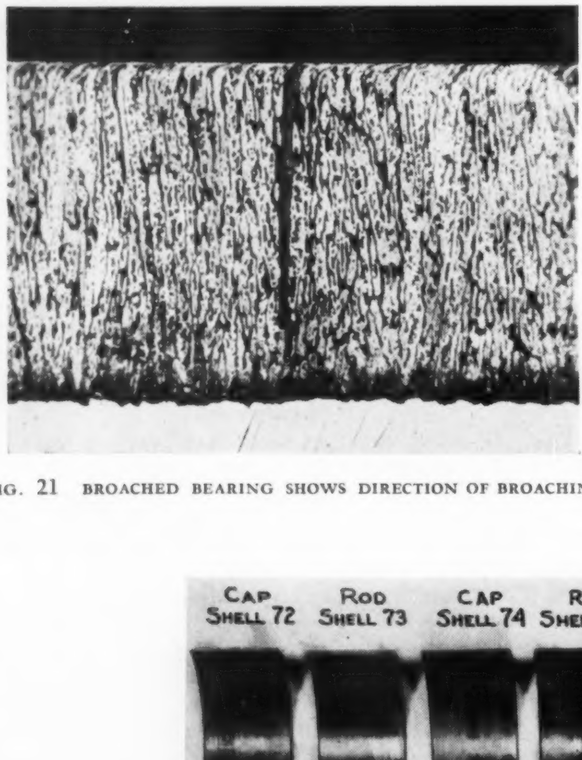

FIG. 21 BROACHED BEARING SHOWS DIRECTION OF BROACHING

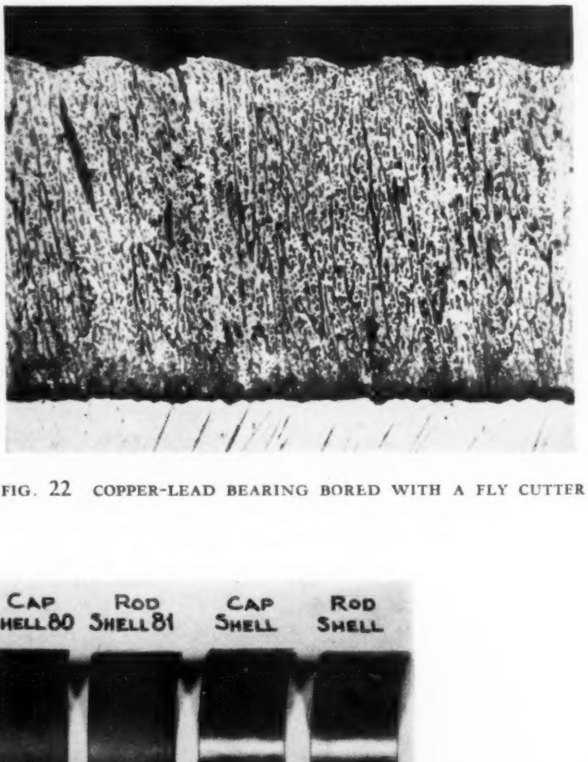

FIG. 22 COPPER-LEAD BEARING BORED WITH A FLY CUTTER

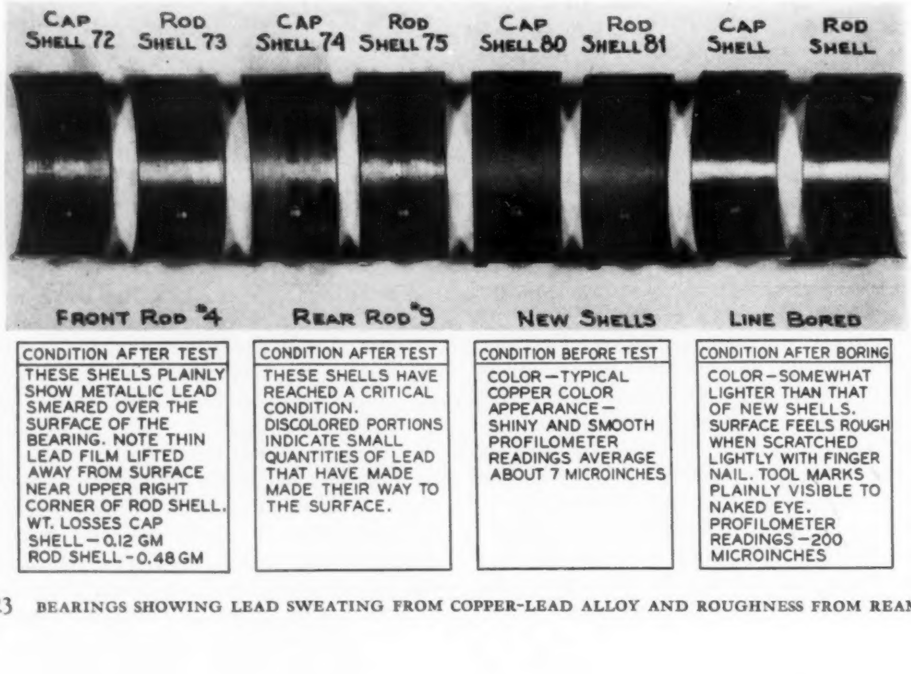

FIG. 23 BEARINGS SHOWING LEAD SWEATING FROM COPPER-LEAD ALLOY AND ROUGHNESS FROM REAMING

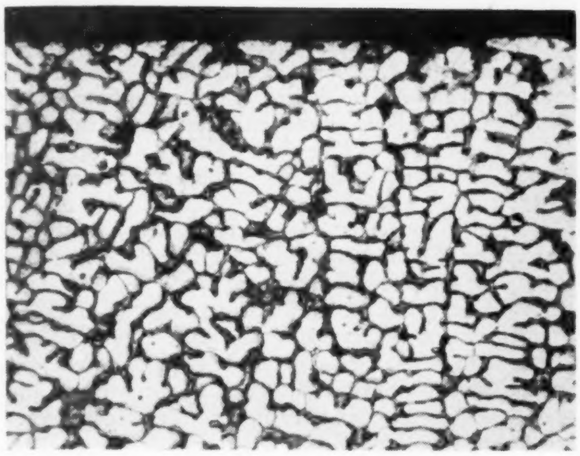

FIG. 24 AN UNCORRODED COPPER-LEAD BEARING
(The lead, the gray structure, extends to the surface of the bearing.)

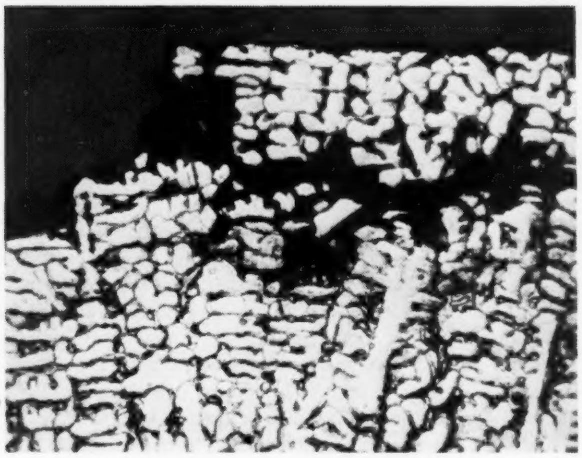

FIG. 25 CORRODED BEARING SHOWING LARGE VOIDS WHERE LEAD HAS BEEN REMOVED

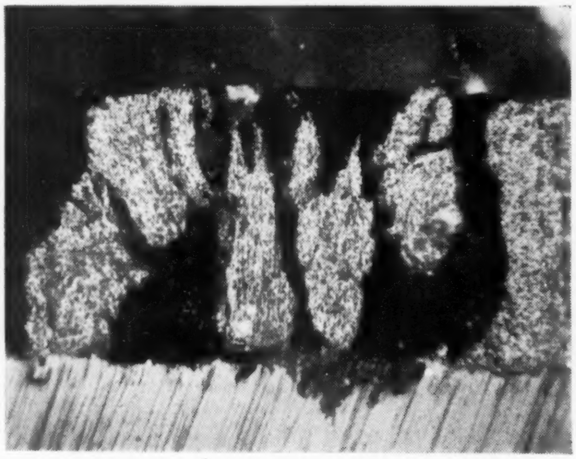

FIG. 26 FINE-GRAIN COPPER-LEAD BEARING FROM A HEAVY-DUTY ENGINE WHICH HAS FAILED BECAUSE OF LOW-TEMPERATURE CORROSION—BOTH THE COPPER AND THE LEAD HAVE BEEN REMOVED

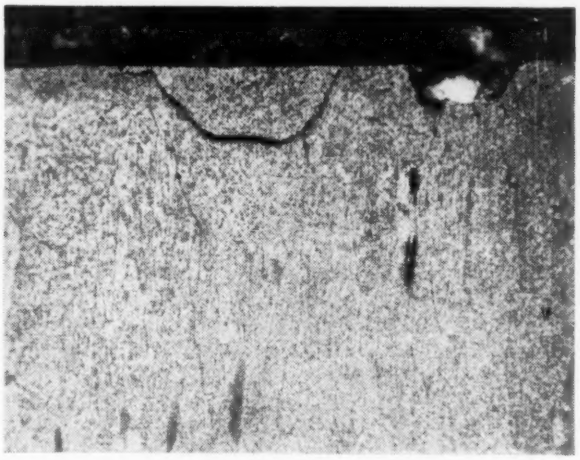

FIG. 27 PHOTOMICROGRAPH OF CROSS SECTION OF MAIN BEARING SHELL WHICH IS NOT CORRODED BUT HAS STARTED TO BREAK DOWN BECAUSE OF FATIGUE

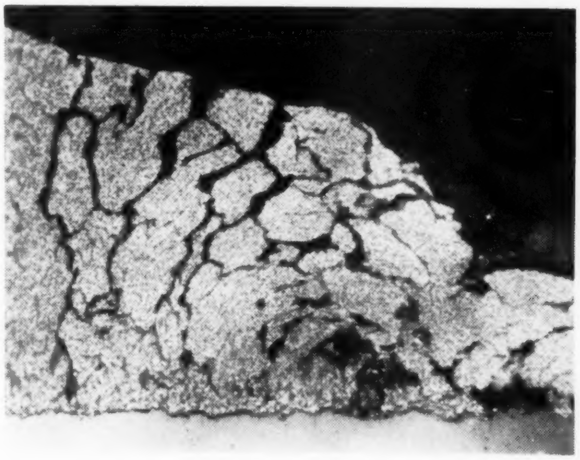

FIG. 28 PHOTOMICROGRAPH OF BEARING FROM SAME ENGINE AS THAT OF FIG. 27 IN WHICH THE FATIGUE HAS PROCEEDED TO TOTAL FAILURE

Fig. 19 is a 500 magnification of a new bearing; the gray lead shows uniformly. Fig. 20 shows a bearing in which the lead has been sweated out by high speed and close clearance. Fig. 21 shows a broached bearing, indicating plainly the distortion of copper matrix and lead at the surface; it is quite smooth otherwise. Fig. 22 shows a bored bearing such as is advocated by one motor company at present. The only feature that can be comprehended is that the ridges crush easily and allow a little of the conformability of babbitt in a hard material. Fig. 23 shows the ordinary view of new reamed and lead-sweated bearings from an actual test to produce lead sweating. It represents close fit, high speed, fairly high load. Fig. 24 shows a new bearing and the coarse grain found in some cases. There is quite a wide difference in makes of copper-lead bearings. Fig. 25 shows how lead has been removed by corrosion. Note how similar this condition is to that of sweating. Fig. 26 shows cold corrosion. Both lead and copper have been removed and black copper sulphide is present, a product not found in hot-corroded bearings. Fig. 27 shows the beginning of fatigue failure in an uncorroded copper-lead bearing. Fig. 28 shows another bearing in the same engine, advanced to full fatigue failure. It is evident that fatigue failures occur also in copper lead.

A corroded bearing, a lead-sweated bearing, and a fatigued bearing may look much alike when removed from the engine. It is only in the earlier stages, before failure occurs, that the type of failure is clearly evident.

TROUBLES AVOIDED BY ATTENTION TO DESIGN

There are some methods by which conditions like this can be cured before an engine goes into production, and it is odd that some of them have not been used long ago. It has been possible, as pointed out, to calculate the flow through the oiling system to every bearing. It is also possible to calculate the heat developed in the bearings so that the maximum temperatures can be predicted with good accuracy. There is nothing abstruse about it; the calculation is rather long and tedious, but it pays very well in saving faulty designs from getting on the market. We have calculated several commercial engines and find weak spots in all of them which can be easily remedied when it is known just what the flows are. Much to the surprise of many designers, it is found that the oil flow through an engine is in general taking place in the viscous region of flow rather than in the turbulent region, that is, the flow is directly proportional to pressure, or nearly so, instead of being proportional to the square root of pressure. In general, with the bearings in ordinary condition, the highest resistance in the system is usually the bearings themselves, which also are always in viscous flow. The author hopes soon to publish a paper on the methods of calculation so that they can be readily used by everybody.

For high-duty engines, there is no question that full-length, long jackets should always be used to keep as much heat away from the crankcase as possible, and in view of the considerable increase in heat rejection to the oil in such designs, oil coolers are likely to be a necessity in the future. The heat-interchanger type of cooler in the jacket system is not entirely satisfactory and the probabilities are that the oil coolers should be air-cooled in the same manner as the water radiator is now cooled. Winter conditions, when the cooler would not be needed, can be met by means of thermostat shutters such as are now used on the water radiator, or by by-passing the cooler. Practically all racing engines—the highest-duty of any—regularly use oil coolers.

Another way of keeping copper-lead bearings out of trouble is to pay a good deal of attention to the finish and fit, especially in repair jobs. A copper-lead bearing requires about twice as much clearance as a babbitt bearing, and we have found in many cases that the maintenance forces in fleet operations often do not realize this, and fit replacement bearings as close as babbitt. This will result in a hot-running bearing during break-in, which is likely to sweat the lead out of the mixture, resulting in bearing failure in a relatively short mileage. Moreover, copper-lead bearings wear the crankshaft much more than babbitt does; in some cases the pins and main bearings are trued up and an undersize shell is used, which is then line-reamed to size. If this job is not carefully done, the bearing is practically ruined by the line-reaming. We find that the bearings coming from the manufacturers have a roughness of 3 to 7 microinches, whereas, after line-reaming, in some cases it may be as high as 200 microinches. In addition, the surface of the metal is left in a clean state for immediate corrosive attack. Of course, line-reaming takes off any protective indium coating that may have been applied.

Another important point to consider is the catalytic effect of clean metal. It is quite possible, in an overhauled engine that has been cleaned too much, that the oil will break down very rapidly. Fig. 29 shows what happened in an engine which was completely overhauled, including reboring, new rings, and chemical cleaning. There is a large amount of fresh metal surface which tends to catalyze the oil, and, in addition, during break-in period, particles of colloidal size are coming off

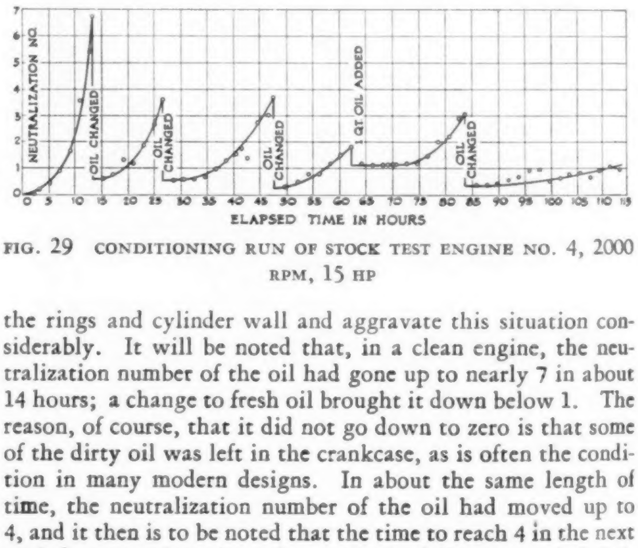

FIG. 29 CONDITIONING RUN OF STOCK TEST ENGINE NO. 4, 2000 RPM, 15 HP

the rings and cylinder wall and aggravate this situation considerably. It will be noted that, in a clean engine, the neutralization number of the oil had gone up to nearly 7 in about 14 hours; a change to fresh oil brought it down below 1. The reason, of course, that it did not go down to zero is that some of the dirty oil was left in the crankcase, as is often the condition in many modern designs. In about the same length of time, the neutralization number of the oil had moved up to 4, and it then is to be noted that the time to reach 4 in the next period was nearly twice as long. In the following periods it is evident that the engine had been conditioned, the catalytic surfaces were poisoned or coated with products of oxidation, and the action was pretty well stopped at the end of 100 hours. It is easy to see, therefore, that overcleaning an engine is not good. The only parts that need cleaning thoroughly are the wearing surfaces. The rest of the engine, provided it is not covered with loose dirt, does not matter and is best left with the coating of varnish or oxidation products that it has acquired.

Deflection or misalignment of as much as 0.002 in. in a 12-in. length can cut the safe load-carrying capacity of a bearing 40 per cent. It is therefore well worth while to see that the alignment is as good as possible between bore and crankshaft, piston pins, and connecting rods. Misalignments caused by distortions of the crankcase in the main bearings are probably the least important, because of length and relative limberness of the crankshaft.

Another trouble, which is not misalignment but distortion, is often found in connecting rods which have been lightened too much. Some of these have quite a limber big end, and it will be found in these designs that the corrosion, when it takes

place, is parallel to the crankpin and generally concentrated at the point where the big end would flex the easiest. There are quite a few connecting rods on the market that do flex under normal loads and these are likely to give bearing trouble. It is interesting to note that in racing engines quite heavy connecting rods are always employed. Many have a four-bolt big end.

At the present time it appears that the major trouble with bearings that are showing difficulty in carrying load or corrosion is high temperature. It can now be stated that internal-combustion engines ought to be designed for crankcase temperatures which do not much exceed 180 F and the lubricating system should be calculated so that there is enough oil flow over all of the bearings to prevent rise of temperature in the bearings themselves from exceeding 35 to 50 deg. Many engines on the market do not meet these conditions. On the other hand, temperatures should not be allowed to get much below 150 F for internal-combustion engines, because of the winter sludge breakdown of oil that is likely to occur. We must not at any time forget that the rate of breakdown of any organic material such as oil will be doubled about every 20 deg F rise and also that corrosion rates will be approximately doubled in the same manner. It appears likely that some such method as has been outlined by the author for calculating oiling systems before the engine is built would save an immense amount of trouble and consequent cost.

GREASE AND SOLID LUBRICATION

Grease lubrication is required for some situations where oil cannot be used; otherwise we probably would not use any grease. A semiplastic material like grease, when in motion, behaves much like a liquid except that it has a variable viscosity with rate of shear. About the only reason for employing grease is to obtain a higher effective viscosity in the bearing than can be obtained with oil, and its use in sleeve bearings is therefore largely confined to bearings running at low surface speed and high load, such as locomotive crankpins, old-style roll-mill necks, and pivot bearings of cranes and turntables. It is also used for cases requiring the ability of the grease to stay in an exposed bearing with much less loss than if oil were used. For this reason grease must be employed for many bearings, such as mine-car journals and exposed conveyer-belt journals, and where hand filling is satisfactory and exposure to weather and water would wash out an oil. The adhesiveness of grease can be made much higher than that of oil, and the change to a semiplastic solid when the temperature is dropped is one of the reasons for its remaining in bearings without high loss. The best lubricating material is an oil; as lubricants, metallic soaps are not as good, in general, as oils.

At present we have only one solid lubricant of commercial value—finely divided graphite. The experimental data on just how graphite works are limited, the best work having been done in England a few years ago, but practical experience has indicated for a great many years that graphite is a valuable ingredient in greases intended for severe or boundary-lubrication cases and it may also be valuable in oil. Its value in break-in of internal-combustion engines is quite noticeable. The action of graphite appears to be somewhat similar to an oiliness agent or an extreme-pressure additive.

BALL AND ROLLER BEARINGS

A word about ball- and roller-bearing lubrication may be of interest since in common practice we often refer to these bearings as "antifriction" bearings. It therefore seems anomalous that bearings which have no friction should need a lubricant. Unfortunately, the beautiful phrase means nothing. Ball bearings do have friction, and at times it may be very considerable. The ball or roller bearing has low starting resistance and the torque is ordinarily not much affected by speed or size for a given load, but if used for high-speed and moderately heavy loads where the friction heat requires a liquid lubricant in quantity to act as a coolant, the friction losses may actually be higher than those for the corresponding sleeve bearing. The friction occuring with a ball and race is made plain from Fig. 30.

The ball A under load and the races B and C are indented under the load W. The uncompressed or free shape of the ball and race is shown by dash lines through points d and e. The relative amount of compression of each of the parts is determined by the shape of the race and the modulus of elasticity, and results in an actual contact line at o. There is no slip at o but because the radius r_1 at o is less than the radius r_2 anywhere else on the ball, the surface velocity is slightly greater as we travel from point o to point f or g. Similarly, in the race the compressed-position radius at o is greater than the unloaded-position radius at f; and the surface velocity of the race is slightly lower than at o. As a consequence, there is an increasing slip between A and B, in either direction from o. The same kind of action occurs between A and C, except that the slip is less. Obviously then, heavy load and relatively low surface speed exist, and the conditions indicate the desirability of oiliness agents or greases. Of course, at high speeds, the surface loads will be kept relatively lighter, but they are in all cases much higher than the surface loads on a sleeve bearing because of very small contact areas. These loads, on large low-speed bearings (for instance those used on roll necks) may exceed 150,000 psi. The rolling friction varies with shape of race for either ball or roller, since the contacts and viscous shears change with the shape.

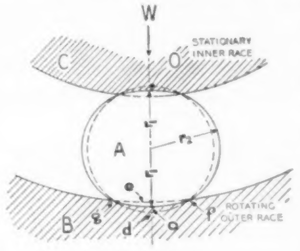

FIG. 30

The second type of loss is largely due to the ball or roller cage, and is also of the viscous-shear type. The cage usually fits quite closely around the ball or rollers. The relative motion gives rise to oil shear just as it does in a sleeve bearing. From this point of view, provided the load requirements under the ball are satisfied, the viscosity should be kept low, since these viscous losses, and consequently the heat generated, increase in proportion to viscosity.

The third type of loss occurs only in a bearing which is flooded with lubricant, or with a grease that flows readily and will not channel, so that it gets in the way of the balls in excess of the slip-lubrication requirements. This loss is of the turbulent type, increasing as the cube of the speed, because the motion of the balls and the cage paddles the lubricant around like a hydraulic brake. It is largely independent of viscosity. It is this third element of friction that gives rise to the high losses in flooded ball bearings at high speed.

The indications are plain. A channeling grease, that will keep out of the way of cage and balls or rollers and only flow a little lubricant as the heat generated melts it down, is desirable to eliminate the turbulent type losses which go up so fast with speed. At low speeds a nonchanneling grease would serve. For lightly loaded high-speed bearings, the oil in the grease should be of as low viscosity as will carry the ball load properly, in order to keep down the viscous-type losses. For heavily loaded, low-speed bearings, it is clear that the rolling condition is controlling, oil of higher viscosity is desirable, and oiliness agents would have distinct value. There is little doubt that a single bearing grease is just as unsuited to all ball-bearing or roller-bearing operations, as a single oil would be for lubricating all sleeve-bearing conditions.

THERMODYNAMIC PROPERTIES *of* AIR

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FOR some engineering purposes, it is sufficiently accurate to consider air to be a perfect gas of constant heat capacity. However, at elevated pressures this fluid deviates significantly from perfect-gas behavior. In many instances, it is desirable to take these effects into account. Graphical or tabular portrayal of the thermodynamic behavior of a fluid permits the solution of many thermodynamic problems, including gas compression, in a fashion simpler than is possible by the use of an equation of state, even though the equation is as simple as the perfect-gas relationship.

With these facts in mind, the thermodynamic properties of air have been computed from existing experimental data at pressures up to 3500 psi in the temperature interval between 32 and 550 F. The isobaric heat capacity of air at infinite volume was computed from the composition recorded by Ramsey (1)[6] and the heat capacities of oxygen (2), nitrogen (3), carbon dioxide (4), argon (5). It was assumed that air was an ideal solution (6) at infinite volume. It is believed that the values obtained by this procedure do not involve uncertainties greater than 0.05 per cent, beyond those associated with the primary-heat-capacity data. The Joule-Thomson coefficient of air, as determined by Roebuck (7)[7] throughout the greater part of the pressure and temperature interval mentioned, was employed to establish the isobaric heat capacity and the isothermal enthalpy-pressure derivative $(\partial H/\partial P)_T$ as functions of state by methods which have been described elsewhere (8). Values of these quantities are recorded in Table 1. It is believed that the graphical solution of the differential equations was carried out with sufficient accuracy to cause no uncertainty in heat-capacity values greater than 1.5 per cent.

Satisfactory measurements of the compressibility factor for air are available at temperatures in the neighborhood of 212 F. The measurements of Amagat (9) were interpolated from 210.92 F to 212 F and were combined with the values obtained by Holborn and Schultze (10). These two sets of data serve to establish the behavior at pressures up to 3500 psi with reasonable accuracy. The volumetric behavior throughout the entire temperature interval was calculated (8) from the values of the enthalpy-pressure derivative recorded in Table 1, and the experimentally determined compressibility factor for 212 F. This indirect procedure was advantageous in the case of air since the deviations from perfect-gas behavior are not large, and the uncertainty in establishing the thermodynamic properties from directly measured volumetric data at a number of temperatures is larger than that resulting from the use of Joule-Thomson measurements.

The specific volume of air was computed from the values of

TABLE 1 HEAT CAPACITY AND ISOTHERMAL ENTHALPY-PRESSURE DERIVATIVE OF AIR

	32 F		70 F		130 F		190 F		250 F	
Pressure, psi, abs	Isobaric heat capacity	Isothermal enthalpy-pressure derivative	Isobaric heat capacity	Isothermal enthalpy-pressure derivative	Isobaric heat capacity	Isothermal enthalpy-pressure derivative	Isobaric heat capacity	Isothermal enthalpy-pressure derivative	Isobaric heat capacity	Isothermal enthalpy-pressure derivative
0	0.2397[a]	−0.008087[b]	0.2400	−0.007063	0.2405	−0.005596	0.2412	−0.004387	0.2420	−0.003485
500	0.2534	−0.007605	0.2531	−0.006593	0.2514	−0.005180	0.2497	−0.003978	0.2486	−0.003125
1000	0.2668	−0.007015	0.2654	−0.006057	0.2617	−0.004696	0.2577	−0.003670	0.2550	−0.002764
1500	0.2785	−0.006290	0.2766	−0.005410	0.2712	−0.004181	0.2652	−0.003200	0.2610	−0.002406
2000	0.2887	−0.005392	0.2863	−0.004681	0.2796	−0.003627	0.2720	−0.002772	0.2665	−0.002047
2500	0.2970	−0.004451	0.2942	−0.003865	0.2867	−0.003048	0.2779	−0.002361	0.2714	−0.001749
3000	0.3033	−0.003419	0.3002	−0.002999	0.2921	−0.002383	0.2827	−0.001869	0.2755	−0.001405
3500	0.3088	−0.002223	0.3052	−0.002078	0.2966	−0.001705	0.2867	−0.001382	0.2791	−0.001063
	310 F		370 F		430 F		490 F		550 F	
0	0.2431	−0.002786	0.2444	−0.002165	0.2458	−0.001635	0.2474	−0.001200	0.2491	−0.000840
500	0.2485	−0.002427	0.2490	−0.001823	0.2496	−0.001318	0.2506	−0.000927	0.2530	−0.000607
1000	0.2537	−0.002095	0.2530	−0.001521	0.2533	−0.001053	0.2537	−0.000674	0.2557	−0.000330
1500	0.2587	−0.001764	0.2572	−0.001237	0.2568	−0.000806	0.2567	−0.000449	0.2583	−0.000137
2000	0.2634	−0.001481	0.2612	−0.000994	0.2602	−0.000595	0.2595	−0.000266	0.2608	0.000046
2500	0.2676	−0.001252	0.2649	−0.000827	0.2633	−0.000442	0.2622	−0.000105	0.2633	0.000184
3000	0.2712	−0.000993	0.2682	−0.000618	0.2662	−0.000264	0.2649	0.000057	0.2658	0.000361
3500	0.2745	−0.000733	0.2713	−0.000388	0.2690	−0.000094	0.2676	0.000228	0.2683	0.000539

[a] Expressed as Btu per lb per deg F.

[b] Isothermal enthalpy-pressure derivative $\left(\frac{\partial H}{\partial P}\right)_T$ expressed as Btu per lb per lb per sq in.

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[6] Numbers in parentheses refer to the Bibliography at the end of the paper.

[7] Corrected values were privately transmitted to the authors on Nov. 23, 1940.

TABLE 2 SPECIFIC VOLUME, ENTHALPY, AND ENTROPY OF AIR

Pressure, psi, abs	32 F			70 F			130 F			190 F			250 F		
	Specific volume	Enthalpy	Entropy	Specific volume	Enthalpy	Entropy	Specific volume	Enthalpy	Entropy	Specific volume	Enthalpy	Entropy	Specific volume	Enthalpy	Entropy
0	....	0.00	..	....	9.11	..	....	23.53	..	....	37.98	..	....	52.47	..
25	7.279[a]	−0.20[b]	0.9635[c]	7.845	8.94	0.9814	8.737	23.39	1.007	9.628	37.87	1.031	10.52	52.39	1.052
50	3.636	−0.40	0.9157	3.921	8.76	0.9336	4.368	23.24	0.9595	4.815	37.76	0.9829	5.261	52.30	1.004
75	2.421	−0.61	0.8876	2.613	8.59	0.9056	2.912	23.10	0.9315	3.210	37.65	0.9550	3.509	52.21	0.9764
100	1.814	−0.81	0.8675	1.958	8.41	0.8856	2.183	22.96	0.9134	2.408	37.54	0.9351	2.633	52.13	0.9566
150	1.207	−1.20	0.8391	1.304	8.07	0.8573	1.456	22.69	0.8834	1.606	37.33	0.9070	1.756	51.96	0.9285
200	0.9038	−1.60	0.8187	0.9774	7.72	0.8370	1.091	22.41	0.8632	1.205	37.12	0.8870	1.318	51.79	0.9085
300	0.6004	−2.39	0.7896	0.6503	7.04	0.8081	0.7274	21.87	0.8346	0.8036	36.70	0.8585	0.8802	51.46	0.8802
400	0.4488	−3.16	0.7686	0.4869	6.36	0.7873	0.5454	21.33	0.8140	0.6033	36.28	0.8382	0.6612	51.14	0.8600
500	0.3581	−3.93	0.7520	0.3887	5.70	0.7708	0.4363	20.81	0.7978	0.4832	35.88	0.8222	0.5298	50.82	0.8441
750	0.2372	−5.79	0.7210	0.2585	4.08	0.7404	0.2912	19.54	0.7680	0.3231	34.90	0.7928	0.3548	50.06	0.8150
1000	0.1773	−7.57	0.6982	0.1937	2.54	0.7180	0.2189	18.34	0.7462	0.2434	33.97	0.7715	0.2675	49.35	0.7941
1500	0.1180	−10.85	0.6646	0.1295	−0.32	0.6852	0.1471	16.14	0.7146	0.1640	32.27	0.7401	0.1806	48.06	0.7638
2000	0.08901	−13.71	0.6397	0.09795	−2.83	0.6609	0.1115	14.19	0.6913	0.1246	30.78	0.7175	0.1373	46.95	0.7418
2500	0.07219	−16.10	0.6198	0.07948	−4.94	0.6415	0.09056	12.53	0.6728	0.1013	29.50	0.6996	0.1116	46.00	0.7244
3000	0.06155	−18.01	0.6034	0.06762	−6.63	0.6256	0.07689	11.17	0.6574	0.08589	28.45	0.6847	0.09464	45.22	0.7099
3500	0.05443	−19.39	0.5897	0.05955	−7.84	0.6122	0.06745	10.15	0.6444	0.07516	27.64	0.6721	0.08271	44.61	0.6976

Pressure, psi, abs	310 F			370 F			430 F			490 F			550 F		
0	....	67.06	...	....	81.68	...	....	96.39	...	....	111.18	...	....	126.07	...
25	11.41	66.99	1.072	12.30	81.63	1.090	13.19	96.35	1.107	14.08	111.15	1.123	14.97	126.05	1.138
50	5.707	66.92	1.024	6.153	81.57	1.042	6.599	96.31	1.060	7.044	111.12	1.076	7.490	126.03	1.091
75	3.807	66.85	0.9963	4.104	81.52	1.015	4.401	96.27	1.032	4.699	111.09	1.048	4.996	126.01	1.063
100	2.856	66.78	0.9765	3.080	81.47	0.9947	3.303	96.23	1.012	3.526	111.06	1.028	3.750	125.99	1.043
150	1.906	66.65	0.9485	2.056	81.36	0.9667	2.205	96.15	0.9839	2.354	111.01	1.000	2.503	125.95	1.015
200	1.431	66.51	0.9285	1.544	81.26	0.9468	1.656	96.08	0.9641	1.768	110.95	0.9802	1.880	125.91	0.9955
300	0.9558	66.25	0.9003	1.031	81.06	0.9187	1.107	95.93	0.9360	1.182	110.85	0.9522	1.256	125.84	0.9675
400	0.7183	66.00	0.8802	0.7753	80.87	0.8986	0.8323	95.79	0.9159	0.8840	110.75	0.9322	0.9448	125.77	0.9475
500	0.5759	65.75	0.8644	0.6217	80.68	0.8829	0.6672	95.66	0.9003	0.7126	110.65	0.9166	0.7579	125.71	0.9320
750	0.3859	65.16	0.8356	0.4168	80.25	0.8543	0.4475	95.34	0.8718	0.4783	110.43	0.8882	0.5087	125.57	0.9037
1000	0.2912	64.62	0.8148	0.3147	79.85	0.8337	0.3380	95.06	0.8514	0.3611	110.24	0.8679	0.3840	125.46	0.8834
1500	0.1968	63.66	0.7850	0.2127	79.16	0.8043	0.2285	94.60	0.8222	0.2441	109.96	0.8389	0.2630	125.33	0.8546
2000	0.1498	62.85	0.7634	0.1619	78.60	0.7830	0.1740	94.25	0.8012	0.1859	109.78	0.8181	0.1976	125.31	0.8339
2500	0.1217	62.18	0.7464	0.1317	78.15	0.7662	0.1413	93.99	0.7846	0.1510	109.69	0.8017	0.1606	125.37	0.8177
3000	0.1032	61.63	0.7322	0.1116	77.80	0.7523	0.1198	93.81	0.7709	0.1279	109.68	0.7882	0.1359	125.51	0.8044
3500	0.09013	61.21	0.7201	0.09739	77.56	0.7404	0.1045	93.73	0.7592	0.1116	109.75	0.7767	0.1185	125.74	0.7930

[a] Expressed in cu ft per lb.
[b] Expressed in Btu per lb.
[c] Expressed in Btu per lb per deg Rankine.

the compressibility factor obtained, using a value of 28.970 for the average molecular weight of dry air. This value was obtained from the measurements of Ramsey relating to the composition, the compressibility factors for the components (11, 12, 13), and the assumption that air constitutes an ideal solution (6) at a pressure of 1 atm. The values of the specific volume of air are recorded in a part of Table 2 as a function of temperature and pressure. It is unlikely that the results involve uncertainties greater than 0.4 per cent at any state.

The enthalpy of air was computed from the isobaric heat capacity at atmospheric pressure and the isothermal enthalpy-pressure derivative by suitable integration with respect to temperature and pressure. The enthalpy at 32 F and infinite volume was arbitrarily taken as zero. The results are recorded as a function of state in a part of Table 2. It is believed that the changes in enthalpy with both temperature and pressure are known with sufficient accuracy so that uncertainties in the enthalpy greater than 0.5 Btu per lb are unlikely. The values have been recorded to one more significant figure than is justified by the absolute uncertainty, in order to permit differences in enthalpy to be established with the desired accuracy.

The entropy was calculated from the isobaric heat capacity and the Joule-Thomson coefficient, which were known as functions of state. The following expression was employed in the evaluation of the changes in entropy

$$S = 1 - b \ln \frac{P}{14.696} + \int_{491.69}^{T} \frac{C_P}{T}\, dT - \int_{14.696}^{P} \left[\frac{\mu C_P}{T} - (1 - Z)\frac{b}{P} \right] dP \quad \ldots\ldots[1]$$

The entropy has been arbitrarily taken as unity for air at 32 F and a pressure of 1 standard atm (14.696 psi). This procedure, involving the use of different datum states for the enthalpy and the entropy, was dictated by convenience and does not introduce any inconsistency (14) in the results. Equation [1] permitted the direct use of the same primary data which were employed to establish the specific volume and enthalpy, thereby insuring consistency among the various thermodynamic properties. Since these experimentally measured quantities contribute only a small part of the total isothermal change in entropy, it is believed that the percentage uncertainty in this property is small. Values of entropy have been recorded as a function of state in a part of Table 2.

For many purposes graphical representation of the thermodynamic properties of a substance is desirable. In Fig. 1 is presented a temperature-entropy diagram for air, based upon the data recorded in Table 2. Lines of constant pressure, specific volume, and enthalpy are shown. The reversal in the sign of the Joule-Thomson coefficient at high pressures and high temperatures is clearly indicated by the slopes of the isenthalpic lines in these regions.

ACKNOWLEDGMENT

The assistance of Louise M. Reaney, in connection with the preparation of Fig. 1, is acknowledged.

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What Is Wrong With "KINEMATICS" *and* "MECHANISMS?"

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INTRODUCTION

In the present emergency, in which this country finds itself, it is of prime importance that the best use be made of every branch of science for the general good. This, however, is possible only when each branch of science is properly applicable to the needs of the moment. This holds true particularly for the technical sciences that have a direct bearing on our defense needs. Numerous fields of engineering require new and, if possible, automatic machinery as well as complicated instruments and other apparatus, the creation of which requires not only great ingenuity, but also a thorough knowledge of mechanical principles and devices. In this respect, one of the foremost and fundamental branches of engineering science is the science of kinematics and mechanisms, without which the creation of such devices can hardly be attempted. While young men are being trained all over the country in special emergency or defense courses which cover a wide range of subjects, one looks in vain for sound courses in this most fundamental engineering science of kinematics and mechanisms. Are men with this specialized knowledge not needed? This can hardly be the case, for even in ordinary times, it is difficult to get men who are proficient in this science. How much more so must this be the case at the present time. Do manufacturing firms prefer to train their men themselves? A certain number of firms actually do this. There are others who leave it to the chief designing engineer to train his own men as he sees fit. Such firms frequently consider their design methods as trade secrets and offer their men inducements to stay with them for long periods. Why do they not entrust this task of training to the colleges where it rightfully belongs?

The mere fact that this condition exists would seem to indicate that college instruction is inadequate to prepare the student properly for positions in practice. Since the instructors in this science are just as intelligent as those in other sciences, it would appear that something must be amiss with the science itself, so that we may reasonably ask: What is wrong with the science of kinematics and mechanisms?

IS SOMETHING WRONG WITH THE SCIENCE OF KINEMATICS AND MECHANISMS?

Before investigating this question, another question will have to be answered, namely: Is there really something wrong with this science? Let us see!

The value of any mechanical science lies in its applicability to the everyday problems of the engineer. If it cannot solve the problems which confront him, it can, at best, be only of limited value, but more often than not, it would be regarded as having little or no value.

The life task of the mechanical engineer is to conceive, design, or operate new and useful mechanisms or machinery. This requires not only vision and imagination, but also mathematical and mechanical skill, and wide experience (which actually is nothing else than what we call the knowledge of the science of mechanisms).

Now, let us watch the engineer in his "workshop." A new labor-saving device is to be created. The idea of such a device may not necessarily come from the engineer. It may have been conceived by the man whose duty it would be to do the work manually. His idea is placed before the engineer, and the latter has to create the desired labor-saving device. With his imagination, he conceives a mechanical arrangement that seems satisfactory. In laying out this arrangement, he faces problems of creating definite motions and of dimensioning suitably the various members of the device. Sometimes, this is a simple problem in geometry or algebra, but more often it will be found that the apparently simple problem is, in fact, very complicated, particularly when velocities and accelerations are involved. When neither geometry, nor algebra will yield quickly a definite solution, the engineer resorts to a trial-and-error process.

Right here, we find the breakdown of our science of kinematics, or of its application to mechanisms! While it does not follow that successful mechanisms and machines cannot be designed in this manner, nevertheless, it is obvious that, if kinematic science were developed far enough to give a ready answer to the problem involved, and, if the engineer had at his command a complete working knowledge of this science, the design of the device would be infinitely simpler and more direct with less chance for trouble, or failure, after the device is built.

If complicated motions are to be realized that require either complex kinematic chains, or the interconnection of various mechanisms, again the task would be infinitely easier if a clear theory of such chains or combinations of mechanisms were available. In the absence of knowledge of such a theory, the engineer once more is obliged to resort to a trial-and-error process. Yet, to his credit, it may be said that, by his ingenuity, or intuition, he frequently arrives at suitable solutions by such a process. Here also, something is obviously wrong!

WHAT IS WRONG WITH THE SCIENCE OF KINEMATICS AND MECHANISMS?

Having thus answered the first question, we may now deal with the other and more important one: What is wrong with the science of kinematics and mechanisms? Why does it not give the answers required of it? Our investigation of this question must be carried on in two directions:

(1) Is it the fault of the engineer, who does not have at his command the appropriate knowledge and, if so, why is this the case?

(2) Is the science itself developed sufficiently far to answer all questions asked of it?

IS ANYTHING WRONG WITH THE EDUCATIONAL FACILITIES?

The first part of our inquiry obviously concerns the educational facilities open to the engineer. How does he obtain

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his knowledge of this science? Again, the answer is twofold, namely, (*a*) by study at a college, or (*b*) by private study. Both these facilities require investigation.

Considering first (*a*), it will be found upon investigating the catalogs of technical colleges in the United States that, in the curricula of their mechanical-engineering departments, courses are offered in "kinematics," or "mechanisms," etc. An inquiry into the subject matter of these courses (naturally not from the catalogs, but from the students themselves and their notes) reveals the astonishing fact that they consist of little more than a description of the layout of certain simple mechanisms, a fragmentary discussion of instantaneous centers and centrodes, some simple rules on velocity diagrams, and a very incomplete and often incorrect treatment of accelerations, gearing and cams usually occupying the major part of the courses.

When inquiring into the personnel which gives instructions in these courses, it is not infrequently found to consist of young men who have only recently completed their own college training by having acquired a master's degree. From where do these young men obtain their knowledge? Are they simply repeating "parrotlike" what they themselves have learned about the subject, thus perpetuating the fragmentary instruction just outlined? Or do they rely on existing textbooks? The latter are far too numerous to be even mentioned here.

Many of the older instructors and professors in this field have, likewise, never been engaged in commercial practice, that is, in the actual design of mechanisms and machines. Therefore they, too, cannot give the student firsthand information on the difficulties that are encountered in the design and layout of mechanisms and machines. Consequently, their knowledge can also be book knowledge only.

This brings us to the second facility (*b*), open to the engineer and also to the college teacher, i.e., private study from textbooks. An investigation of these textbooks brings to light the curious fact that they are all strangely similar in their incompleteness. Obviously, they all go back to the same source and differ only in details or the extent of the material discussed which, in practically no case, goes beyond that previously outlined for the subject matter of the courses.

IS ANYTHING WRONG WITH THE SCIENCE ITSELF?

The second part of our inquiry concerns the science of "mechanisms" itself or, as it is sometimes called, "kinematics," or "kinematics of machinery." To begin with, a distinction must be made between the science as known and taught in the United States and Great Britain and that as known and taught on the European Continent, particularly in Germany. The mere fact that such a subdivision is necessary shows that here too something must be wrong!

Let us first consider the science as taught in the United States. This is reflected not only in the state of the textbooks as previously outlined, but also in the attitude of practical engineers. Without fear of contradiction, it can be stated that many practical engineers and, for that matter, also many college professors consider the subject as being antiquated, fully developed, and incapable of further extension; in other words, they consider it as a stagnant or stale science which it may be useful to know, but which is hardly capable of solving even slightly complex practical problems, not to speak of really difficult ones. As stated previously, the practical engineer prefers to use a trial-and-error process rather than to waste time in attempting to find a mathematical or a kinematical solution for his problems. Why does such an attitude exist in this science, while the very opposite holds true for almost every other technical science? Obviously, the science as known here must have certain shortcomings!

Since it must be admitted that the science of mechanisms is based on correct principles and, thus, has a secure foundation, why is it then that it has become so stale and stagnant, and why can it not take care of the solution of practical problems?

On the other hand, the science as taught in Europe, especially in Germany, is a very live science that has become fruitful and is widely used by practical engineers in that country. As might be expected in such a case, numerous modern and greatly advanced textbooks have been published there, particularly during the last decade or so. Yet, even there, this science has arrived at a deadlock as will be shown later on. Thus, there, too, must be something vitally wrong!

To find out what is wrong with these two presentations of this science, it is necessary to delve a little into its historical development.

HISTORICAL DEVELOPMENT OF THE SCIENCE

Period From the Founding of This Science to Reuleaux. Shortly after the establishment of the first technical college, the École Polytechnique at Paris, in 1794, mainly by the energetic efforts of the celebrated French mathematician, G. Monge, the study of mechanisms was separated by him and S. Carnot from both general mechanics and the science of machines. The new college became immediately the center at which the young science was cultivated and taught, first by Hachette, and later by Lanz and Bétancourt and their successors, all of whom advanced it materially. In the beginning, it consisted of little more than a description of the mechanisms and of an analytical treatment of the motions occurring in them. In 1834, A. M. Ampère gave the new science the name "cinématique" (kinematics) and outlined its scope which, according to him, was to be the mathematical investigation of the motions that take place in mechanisms and machines, and the investigation of the means for creating these motions, namely, of the mechanisms and machines themselves.

Important progress in the first of these two branches was made when M. Chasles and L. Poinsot, at the instigation of Ampère, introduced the geometrical treatment of the motion of rigid bodies by means of the so-called "instantaneous center" which had been discovered much earlier by Johann Bernoulli and had been used by L. Euler. This new viewpoint changed the aspect of the geometry of motion completely and led to many important investigations. A great mass of information was accumulated, particularly by the brilliant work of the French mathematicians of that period and, to a lesser degree, also by those of Great Britain and Germany. While this information was of great value for the investigation of existing mechanisms, it proved of little use for the creation of new ones. Yet, it is mainly the creation of new mechanisms that forms the real test for the value of this science. Thus, attention became focused on the second branch.

By studying the mechanisms themselves, it was assumed to be possible to arrive at the basic laws of their composition. According to Ampère's definition, the purpose of mechanisms was the change of one motion into another. Consequently, all investigations since Ampère concentrated on this aspect. However, the discovery of such basic laws proved to be a much more difficult task than had been anticipated; in fact, it defied the efforts even of the ablest minds of that period. Thus, the conviction slowly gained ground that no such basic laws existed, and that it was futile to try to evolve a general system of kinematic analysis and classification.[1] In order not to delay progress in the first branch, kinematics, in France, was separated, during the middle of the nineteenth century, into two distinct branches, "cinématique pure" and "cinématique

[1] This example demonstrates the folly of using a definition as a basis for an investigation!

appliquée" (or theoretical and applied kinematics). While the first branch rapidly advanced, the second one proved unfruitful and soon became reduced to a mere description of mechanisms and, for want of a better system, to the use of the antiquated and entirely inadequate system of analysis and classification based on the conversion of motion, which originally was evolved by Lanz and Bétancourt from a program suggested by Monge. This situation remained unchanged until about 1864.

Advance of Applied Kinematics by Reuleaux. The first real advance in applied kinematics was made by Prof. Franz Reuleaux, of Germany, who, disregarding all previous attempts, approached the subject from an entirely new angle, not from the mathematical end by investigating the motions produced, but from the end of the finished product, the machine itself. By considering the motions of the machine parts as enforced or "constrained" motions, he found this constrainment to be due to the form of the elements, by means of which the members are connected. He recognized further, that these elements never occur singly, but always in "pairs," that several elements may be combined into a "link," and that links may form what he termed a "kinematic chain." Upon these concepts, the element pair, the kinematic chain, and the constrainment of motion, he attempted to build up a logical theory of mechanisms and of machines, which he accomplished with a fair degree of success.

Reuleaux made his investigations known for the first time in a lecture before the Swiss Congress of Natural Science at Zürich in 1864 (1).[2] Between 1871 and 1874, he published further researches under the title "Kinematische Mitteilungen" (2), which he collected, extended, and published in 1875, as the first volume of his now classical work "Lehrbuch der Kinematik" (3). This first volume was very ably translated into English by Prof. A. B. W. Kennedy of University College, London, and published in 1876 (4). Reuleaux's treatise created a sensation. The simple and straightforward principles it contained were readily accepted by engineers everywhere, and, after they were adopted by Professor Kennedy in his treatise on "Mechanics of Machinery," 1886, the English translation of Reuleaux's work became the classical basis for all other textbooks on mechanisms published in the English language, that is, it became the source previously referred to.

Within the next quarter of a century, little was added by others to the structure Reuleaux had created. This is hardly surprising, for it bore so obviously the stamp of simplicity and finality that it seemed incapable of further improvement. The most important extension to Reuleaux's system was the treatment of complex kinematic chains by T. Rittershaus (5) (1875 and 1876), and later by M. Grübler (6) (1883 to 1885), the latter adding to it criteria for the constrained movability of such chains.

Reuleaux himself used these twenty-five years to consolidate and simplify his science, to round it out, and to add to it wherever necessary. Applied kinematics reached its zenith in 1900 with the publication by Reuleaux of the second volume of his "Theoretische Kinematik," to which he gave the title "Die praktischen Beziehungen der Kinematik zur Geometrie und Mechanik" (The Practical Relations of Kinematics to Geometry and Mechanics) (7). Unfortunately, this extraordinarily important volume was never translated into English, a fact, which undoubtedly accounts for the astonishingly little progress that applied kinematics has made in the English-speaking countries.

After giving a number of important geometrical methods for the investigation of motions in mechanisms, Reuleaux established in this volume a general system of analysis and a clear classification of mechanical and hydraulic devices by arranging them in but six classes, thus reducing the seemingly infinite number of such devices to a small number of general classes and thereby simplifying applied kinematics considerably. These classes are discussed in a previous paper (8) by the author.

At first, Reuleaux's ideas were readily accepted in Germany and abroad. However, like many great men, Reuleaux had numerous enemies, by whose efforts the false statement was widely circulated that the "science of constrained motion," as Reuleaux preferred to call this science, was of little practical value. Because this statement apparently was borne out by certain shortcomings in Reuleaux's system, interest in this subject slowly abated. With Reuleaux's forced retirement, in 1896, from the technical college of Charlottenburg, which was established mainly by his efforts, the teaching of applied kinematics receded into the background and was soon removed almost entirely from the curricula of German technical colleges. When, with Reuleaux's death, on August 20, 1905, his driving spirit passed away, a period of stagnation in this branch of kinematics started.

Advance of Theoretical Kinematics Since Reuleaux. Although Reuleaux's remarkable personality overshadowed the advancement of theoretical kinematics, that is, of the mathematical treatment of motion, nevertheless, this branch too was developed rapidly. As stated, a great mass of information had been established in the course of time, but the investigations were widely scattered throughout the literature. Thus, the necessity for collecting and correlating this material into a unified structure became all too obvious. Although several such attempts had been made in France as well as in Germany and Great Britain already before Reuleaux's time, none of these attempts succeeded in establishing a simple and clear system for the treatment of kinematic problems in general. The first successful attempt at establishing such a unified system, by collecting and correlating the fundamental theorems of kinematics and by adding to them new ones of his own, was made in 1872, at the instigation of Reuleaux himself, by his colleague Prof. S. Aronhold, in a paper entitled "Grundzüge der kinematischen Geometrie" (Principles of Kinematic Geometry) (9). The effect of this brief but excellent treatise by Aronhold was that, in Germany, a number of mathematicians and engineers of that period took up energetically the study of this branch of kinematics. Numerous individual problems were solved particularly by T. Rittershaus, L. Burmester, O. Mohr, A. Ramisch, R. Mehmke, and others.

A second attempt at evolving a treatise on "geometrical kinematics," based on geometrical methods, was made by A. Schoenfliess, in 1886, under the title "Geometrie der Bewegung in synthetischer Darstellung" (Geometry of Motion in Synthetic Treatment) (10).

The first comprehensive systematic textbook on theoretical kinematics, that is, on the geometry of motion, was published in 1888 by L. Burmester of Germany (11). In this extraordinary work, Burmester collected all of the important mathematical (mostly geometrical) methods known at that time, correlated them, and added to them numerous new ones of his own, in which he, like his two predecessors, made the widest use of the methods of projective geometry.

It is, indeed, very unfortunate that none of these three treatises has been translated into English. This fact, coupled with the extensive use made, in all three, of projective geometry (a subject seldom taught engineers in Great Britain and the United States), provides the explanation why kinematics has not been developed in the English-speaking countries to any great extent, and why these important treatises are there scarcely known even by name. It is, therefore, not surprising to find

[2] Numbers in parentheses refer to the Bibliography at the end of the paper.

in these countries a complete ignorance of the simple and powerful methods contained in them.

The seeds sown by these three pioneers soon bore rich fruit. Not only in Germany, but also in France and Italy, geometrical kinematics was advanced rapidly by many scientists. Of these, only the most outstanding ones can here be mentioned. These are in Germany: O. Mohr, R. Mehmke, A. Schoenfliess, Reinhold Müller, C. Rodenberg, H. Weiss, K. Heun, H. Meuth, L. Burmester, R. Land, W. Hartmann, M. Krause, F. Wittenbauer, H. Alt, Th. Poeschl (Austria), R. Beyer, K. Federhofer (Austria), and many others; in France: M. Lévy, C. Stephanos, A. Mannheim, G. Koenigs, H. Poincaré, R. Bricard, and many others; in Italy: especially L. Allievi who greatly advanced the theory of the motion of a rigid system (12). Even in England, numerous kinematic problems were attacked and successfully solved, although by entirely different methods. The names of S. Roberts, J. J. Sylvester, W. K. Clifford, W. Burnside, A. Cayley, Th. Preston, and others may be mentioned. In the United States, little original research was carried out, the most outstanding kinematician having been perhaps Prof. A. W. Klein.

Little of the investigations of all these men seems to have become known in the United States. For this reason, it is well worth outlining briefly the progress brought about by their efforts.

NATURE OF THE PROGRESS MADE SINCE REULEAUX

To begin with, these European kinematicians have developed a general system of treatment for all kinds of kinematic problems. Starting from the most general motion of a rigid body, or system, general laws have been evolved for it, and all mechanisms appear simply as special cases of this general motion. In Great Britain and the United States, on the other hand, the mechanisms have been considered as the fundamental units, and the motions of each type have been investigated by whatever method seemed most convenient to the particular author. Thus, a multiplicity of methods is used in these countries for various mechanisms instead of a single general method applicable to all. This holds true particularly for the determination of accelerations in mechanisms. Not until quite recently has some progress been made by a more general application of velocity and acceleration polygons, but these have, by no means, found their way as yet into all, or even into the majority of textbooks published in these countries. As it is not permissible to generalize from special cases, that is, from mechanisms, it is not surprising that general laws have not been uncovered in these countries.

KINEMATIC SYNTHESIS OF MECHANISMS

If the investigation of motion in existing mechanisms were considered to be the sole objective of the science of kinematics, it would rightfully have to be regarded as being only of limited value. To be a vital science, its principal aim must be, as previously stated, the creation of new mechanisms, or of mechanisms that fulfill given or desired conditions. Quite generally, this purpose must be classified as the "synthesis of mechanisms." With regard to time, two separate periods of development of kinematical synthesis have to be distinguished, the first starting about 1875 and lasting into the "nineties" of the last century, and the second starting after 1910 and still continuing at the present time. According to the two branches of kinematics, the approach in the first period was twofold. The approach from the "mechanismal" end was accomplished by Reuleaux (3, 4) who, in conformity with the treatment used by him in his analysis of mechanisms, used for this new purpose, the laws of the composition of mechanisms, thus reversing the process of their analysis established by him. In this way, he created a kind of synthesis which is now called "type synthesis," because "mechanismal" types are created by the composition of elements. A second approach from the "mechanismal" end was that by M. Grübler (6), who used the theory of constrained movability of complex kinematic chains, evolved by him, to produce new constrained movable mechanisms. Thus, he created a kind of kinematic synthesis, which is now called "number synthesis," because it makes use of the numerical relations that exist between the number of element pairs (lower and higher) and the number of links in the chain, to create new chains. This kind of kinematic synthesis is still of the greatest importance.

The approach from the mathematical end was carried out first in Great Britain by A. B. Kempe (13) and later on in Germany by L. Burmester (11) and others. Characteristic of this approach is the attempt to generate given curves by mechanisms; in particular, the problem of true and approximate straight-line motions found many solutions, although Kempe had solved already the far more general problem of generating any given algebraic curve by a link mechanism and had shown how the latter may be obtained. For the investigation of straight-line motions, Burmester, on the other hand, devised methods which, much later, were found to be quite fundamental and suitable for forming the basis of a new kind of kinematic synthesis. The creation of this latter, however, was not accomplished until the end of the second decade of this century.

The reason why the attempts to develop kinematic synthesis further came to a halt at the end of the last century was that the formulation of problems resulting from practical applications is unsuitable for a direct treatment. Such formulations had first to be adapted to new methods of solution which had not yet been developed. In a large measure, this is the principal difficulty even today. The close relationship between formulation of a problem and the respective method of solution has been of decisive influence on the development of kinematic synthesis. In scarcely any other field of science is the ability to solve numerous problems so dependent upon the ability to formulate them in a suitable manner, as in the case of kinematic synthesis (14).

The second period started about 1910, at which time M. Krause (15) published an analytical method that permitted not only the investigation of the motions in mechanisms, but also the solution of the opposite problem, namely, the determination of the motion of a plane system from given conditions. Although his method is perfectly general, it is applicable only to conditions that can be formulated in terms of mathematical equations. In practical problems, in which the conditions are usually given graphically, or in the form of any curves, this analytical method naturally fails.

The first successful attempt to use geometrical methods for the solution of a variety of problems to create mechanisms which fulfill given conditions was that of M. Grübler (16) who gave several new formulations of such problems and developed methods by which they can be solved. He also pointed out the importance of some of Burmester's investigations for the kinematic synthesis of mechanisms. Using these latter as a basis, several German kinematicians have developed during the last two decades a new kind of kinematic synthesis which, since its main object is to determine the relative sizes of the members of a mechanism so as to suit given conditions, may be called "size synthesis." The initial development of this size synthesis is due to H. Alt (14) who, with R. Beyer and others, is now carrying on this work which is still far from completion.

Of all these developments scarcely anything is known in the United States, where the principal objective of kinematics is still considered to be the analysis of motion, that is, the deter-

mination of displacements, velocities, and accelerations in existing mechanisms. The statements that there is much wrong with the science of kinematics and mechanisms as taught here in the United States, and that the textbooks scarcely contain any of the progress made since Reuleaux's time (1875) are, therefore, true and fully justified. The only books which give some of the early developments of the theory of kinematic chains due to Grübler are those by A. W. Klein (17) and R. C. H. Heck (18).

What is wrong with the science as developed in Germany?

After having shown what is wrong with the teaching of kinematics and mechanisms in the United States, the statement has to be proved that even in Germany, where this science has been advanced farthest, applied kinematics has arrived at a serious deadlock, and that, consequently, there too, something must be vitally wrong with it.

To understand the difficulties in which German kinematicians find themselves, it is necessary to discuss briefly a new development which has taken place in that country.

For a long time, it had been felt that there existed gaps in Reuleaux's kinematic analysis and classification, because, by Reuleaux's method, it was not possible to analyze and classify electrical devices for example. Nevertheless, many of Reuleaux's former students considered that a great injustice had been done their former professor and master by suppressing almost completely his applied kinematics in the German colleges. As the result of conferences among them, a Reuleaux Society (proposed by Prof. R. Hundhausen) was founded on September 9, 1921, for the purpose of furthering kinematics in general and Reuleaux's applied kinematics in particular. Some of Reuleaux's former students tried to fill out the gaps left in his system. So far, however, only one attempt has been moderately successful, namely, that by Prof. Rudolf Franke of the Technical College of Charlottenburg. In a booklet published by him in 1930 (19), Franke shows how, with the aid of three new concepts, declared by him to be fundamental, applied kinematics, cloaked in a new garb, may be built up so that electrical devices can assume therein their proper place. However, by these new concepts, he has created such a confusion in the older Reuleaux kinematics that the Committee on Mechanisms of the Verein deutscher Ingenieure considered it necessary to convoke a special congress on July 13 and 14, 1934, to deal with the "Necessity of Modifying and Developing Further the Theory of Mechanisms," and to discuss, among other things, the question how the fundamental concepts of Franke's new science could be reconciled with those of the older Reuleaux science. Although Franke delivered two papers at this congress, the discussion which followed did not bring about the desired result (20). Since then, three further congresses on kinematics and mechanisms have been held (the last one on September 20 to 22, 1937, at Düsseldorf) and also numerous round-table conferences, but the important problem, how the two sciences of mechanisms by Franke and Reuleaux can be reconciled, one with the other, has not yet been solved (21). German kinematicians have since been satisfied to regard Franke's science as a sort of extension to Reuleaux's science, but voices have not been lacking who defer decision on Franke's work (22).

It may be shown easily, however, that Franke's science is based upon wrong premises. Furthermore, it has become evident that Reuleaux's science has several gaps which must be filled out. When, however, Franke's premises are suitably corrected, and when, in addition, a new general kinematic concept of basic importance is introduced, it will be found that both Franke's and Reuleaux's kinematics form part of a far more general science of mechanisms, which comprises the entire field of engineering,[3] and thus brings to realization the science that Reuleaux had envisioned.

Conclusions

In summing up, it has been shown that the science of kinematics and mechanisms as taught in the United States is based mainly on developments that date back to about 1875, and does not take into consideration the extensive progress made since that time in Europe and, particularly, in Germany. Consequently, manufacturers of intricate machinery are quite justified in not obtaining their men from the colleges which are so backward in the teaching of this science, but rather in training them themselves by teaching them in practice those methods which they have found useful or suitable in the work upon which they are engaged. That this is neither a desirable nor a healthy state of affairs can hardly be questioned.

On the other hand, it has been shown that, even in Germany, where this science has been advanced furthest, considerable difficulties remain to be overcome. However, when these obstacles are surmounted, this science will not only be one of the most fundamental engineering sciences, just as mathematics and general mechanics, but will become a universal science that should be studied by every engineer interested in mechanisms and problems in which motion plays a part. For this science provides a cross section through the entire field of engineering, as it draws its examples from every branch. Consequently, it forms a valuable antidote to the overspecialization so rampant at the present time. The student thereby comes in contact with problems in many branches of engineering which, otherwise, he would never think of studying; hence, his horizon widens. Applied kinematics, in addition, is of the greatest importance to patent attorneys and patent examiners alike, because a correct evaluation of any mechanism or machine becomes possible only by the application of its general laws.

The question whether this science can solve *all* problems that occur in practice must be answered in the negative for the time being. Nevertheless, a considerable number of problems relating to the synthesis of mechanisms can already be solved by present-day methods, and the number of such problems as well as that of the methods by which they can be solved is steadily increasing. The United States, however, is not as yet participating in this development.

It is this considerable increase in the knowledge of kinematics, brought about by the modern methods of the synthesis of mechanisms, and the simplification of the older methods of kinematic analysis and classification, which the author desires to bring to the attention of the engineering profession and, particularly, of the colleges, which should be interested most in this development. From what has been said, it has become all too obvious that instruction in this science should be completely revised. American colleges give their students a predominantly analytical education, yet, to a large extent, neglect instruction in geometrical methods. Analytical methods, although suitable for certain subjects, are, however, wholly inadequate for the design of machinery, because design on the drawing board requires geometrical methods as the logical means of approach.

The modern development of both the analysis and the synthesis of mechanisms depends largely on the judicious use of "projective geometry," formerly a subject in American colleges, but now no longer taught there, due probably, to the fact that practical applications requiring its use were not known at the time when it was dropped from the curricula. As modern kinematics has changed this situation, and as projective geometry is a necessary prerequisite for it, it follows

[3] This science has been developed during recent years by this author and will be published elsewhere in due course.

that projective geometry must be reintroduced in the colleges before the modern development of kinematics can be presented to engineering students. The teaching of these modern kinematic methods would not only be of direct benefit to the students, but also to industry and the country as a whole, because the haphazard trial-and-error methods, with their accompanying waste of large sums of money, can then be eliminated to a considerable extent. In addition, American engineers would thereby be enabled to take part in the further development of this science. Then, German kinematicians could no longer boast, as they have repeatedly done (23), that this is almost entirely a German science, and that Germany is so far in advance of other countries in this respect that German industry can afford to wait until the rest of the world has caught up with it in the use of this science.

Whether any benefit can be derived from such a reorganization of college instruction in this science in time to be of value in the present emergency depends entirely upon the speed, farsightedness, and courage with which such reorganization would be effected. To have here, for the first time, drawn attention to this very neglected field of science is the purpose of this somewhat sketchy review of progress elsewhere.

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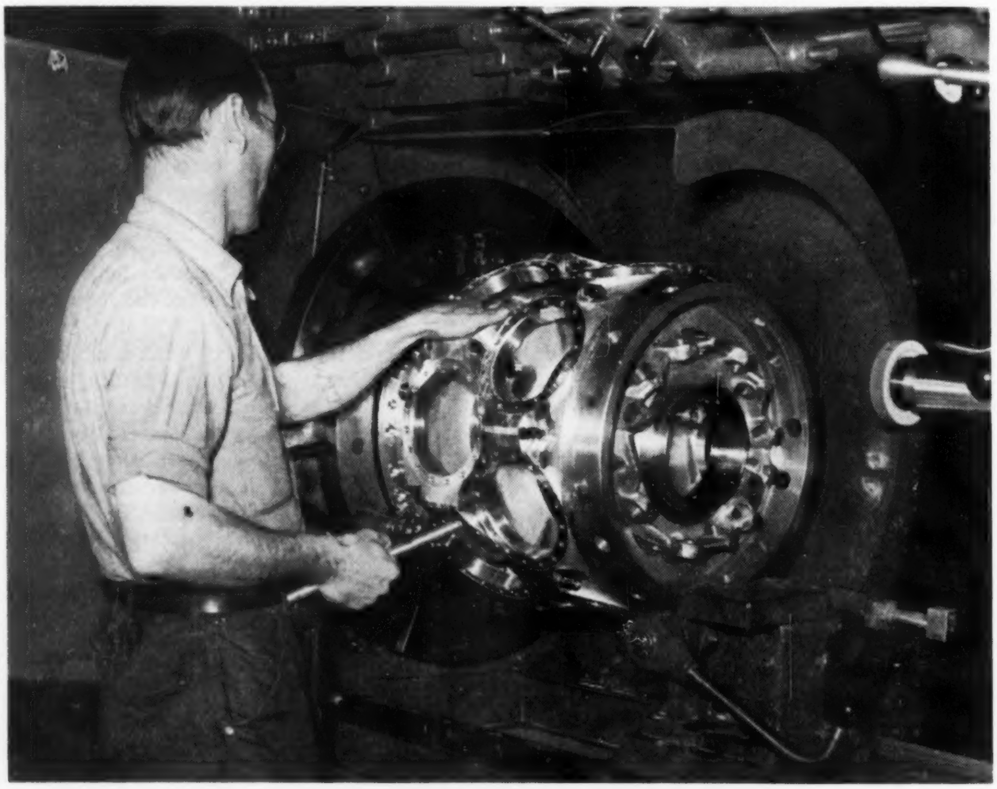

GRINDING SETUP ON BUICK'S AIRCRAFT-ENGINE JOB

MARINE BOILERS

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BECAUSE of the importance of weight in a ship, when designing marine boilers, emphasis is always placed on making a unit as light as possible consistent with the requirements of the service, type of feedwater to be anticipated, accessibility for cleaning and repairs, and continuity of service. When a ship is at sea, the boilers should at all times be available, and both the design and operation should be such as to assure this result. Unlike the average stationary boiler, all marine boilers are supported from below and never suspended from above. This is to save weight, and also to assure proper stability when a ship is pitching and rolling in a seaway. Before taking up design characteristics of marine boilers and the trend that has been taking place in them, it will be interesting to review just what must be done by equipment of this kind in generating steam from the fuel and water brought to it.

Assume that a cubic foot of fuel oil is burned efficiently and all of the available Btu (1,136,000) are utilized in generating steam from water at 250 F. Table 1 shows the volumes of water and steam that would be handled under these conditions.

TABLE 1

Steam conditions	Cubic feet of feedwater at 250 F	Cubic feet of steam
300 Psi; 500 F; 80 deg superheat	18.6	1834
400 Psi; 700 F; 250 deg superheat	16.9	1579
600 Psi; 850 F; 360 deg superheat	15.9	1135
1200 Psi; 900 F; 320 deg superheat	15.8	574

If the products of combustion are cooled to approximately 350 F, the gases formed by burning 1 cu ft of oil would occupy a volume of approximately 20,000 cu ft.

The effect of pressure and temperature upon the quantity and distribution of heat required to produce 1 lb of steam from water at 250 F is outlined in Table 2.

TABLE 2

Steam Pressure, psi	Temp, F	Sensible heat to water Btu	Per cent	Latent heat Btu	Per cent	Superheat Btu	Per cent
300	500	180.3	17.4	804.4	77.5	52.6	5.1
400	700	209.6	18.3	776.5	67.9	157.3	13.8
600	850	256.2	21.1	728.3	59.9	231.6	19.0
1200	900	355.3	29.1	608.9	49.8	257.5	21.1

As may be noted from Table 2, as the pressures and temperatures increase, the percentage of latent heat decreases, and both the heat of the liquid and the heat used for superheating the steam increase. These thermal characteristics of steam at different pressures and temperatures have their logical effect upon boiler design to meet these different requirements, the duty of the boiler surface becoming proportionately less and that of the superheater and economizer (or feedwater heater) surfaces becoming correspondingly greater with increasing steam pressures and temperatures.

The pressure and the temperature of the steam generated by a marine boiler are determined by the requirements of the propulsion machinery. As knowledge of the art of designing and building steam machinery has progressed, the design and manufacture of boilers has kept pace, resulting in improved thermal efficiency and better operating economy of the ship. Table 3 gives the approximate over-all performances that may be expected from marine installations, utilizing the steam conditions specified.

TABLE 3

Steam conditions Pressure, psi	Temp, F	Pounds of 18,500-Btu oil per hour per shaft horsepower (all purposes)
300	500	0.80
400	700	0.62
600	850	0.57
1200	900	0.50

It is because of the trend, shown in Table 3, that steam pressures and temperatures have been gradually increasing in steam-driven ships, moving up as rapidly as progress in the art of building the propulsion machinery has justified such increases commercially.

BOILER UNITS

Marine boilers and furnaces and supplementary heat-absorbing equipment such as superheaters, air heaters, and economizers, when used with them, are so closely associated that any such combination is referred to as a boiler unit.

Scotch Boilers

Until about fifty years ago, practically all steam used for propulsion of ships was generated in fire-tube boilers (gases inside the tubes), the Scotch boiler being the most popular type of such units for both naval and merchant-marine service. Fig. 1 shows the essential characteristics of a Scotch boiler equipped to burn oil fuel and fitted with a small air heater. Because of the necessity of using relatively heavy shell plates, with suitably stayed flat heads, a Scotch boiler is a heavy and inflexible structure for the purpose intended, and is seldom built for operating pressures in excess of 250 psi. Scotch boilers, without water, weigh in the neighborhood of 50 lb per sq ft of boiler heating surface; the water at steaming level and temperature weighs approximately 20 lb per sq ft, making a total of 70 lb per sq ft of boiler heating surface. Because of its inflexible construction and relatively poor circulation characteristics, it is not usual to "force" boilers of this type, with the result that from 10 to 15 lb of boiler are required per pound of equivalent evaporation per hour at full power.

At about the turn of the century, active steps were taken in both the Navy and merchant marine, to explore the possibilities of water-tube boilers. The lack of proper knowledge of feedwater conditioning made early progress with water-tube boilers in the marine field somewhat slow, but their inherent advantages for this duty (reduction in weight and ability to "force" them when necessary) gradually overcame the resistance to their use, so that today their acceptance is almost universal in new American-built steam-driven tonnage.

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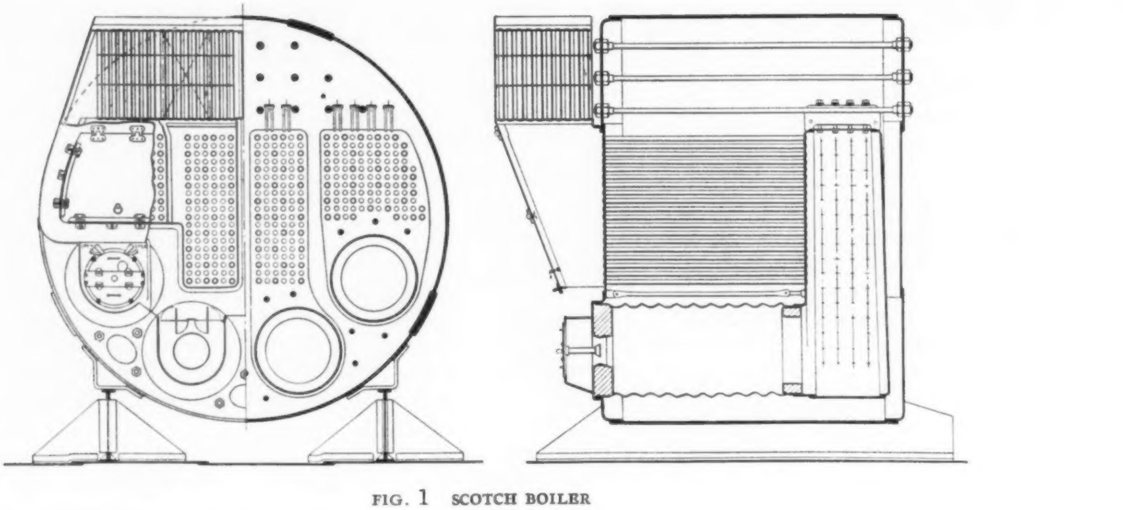

FIG. 1 SCOTCH BOILER

Three-Pass Header-Type Boilers

Because of the necessity for frequent manual cleaning of the water surfaces in the early days of water-tube boilers, the use of straight and readily accessible tubes was emphasized. A boiler of this type which enjoyed wide popularity is shown in Fig. 2, where 4-in. tubes were used throughout the boiler surfaces; the superheater, which is located at the top of the first and second passes of the boiler, being made of 2-in. tubes. These 4-in-tube units, with water at steaming level and temperature, weigh approximately 40 lb per sq ft of boiler heating surface, and 7 lb per pound of equivalent evaporation per hour at full power, which is an appreciable saving compared to Scotch boilers of similar capacity.

The extensive operation in the merchant marine of boilers of this general type during and following the last war gave a great number of marine engineers, who up to that time had never handled anything but fire-tube boilers, an opportunity to become familiar with marine water-tube boilers and their advantages.

Although the 4-in-tube header-type boiler, as shown in Fig. 2, was a decided improvement over the Scotch-type boiler from a weight and accessibility point of view, appreciable improvement in the way of further weight reduction and saving of space in the fireroom could be made by using tubes of smaller diameter. Fig. 3 shows tube groupings that have been used in header-type marine boilers, the reduction in diameter of the tubing used, and its more compact arrangement appreciably affecting the weight characteristics of a boiler unit of this type. Table 4 shows the essential effects of the progressive reduction in tube diameter, utilizing the tube arrangements shown in Fig. 3, assuming average merchant-marine steam pressures in the neighborhood of 400 to 500 psi.

TABLE 4

Size of tubes, in.	4	2	1¼	1
Gage of tubes, no.	6	10	13	13
Tubes per handhole fitting	1	4	9	14
Heating surface per handhole fitting (tubes 10 ft long), sq ft	10	20	28	35
Weight per square foot of heating surface, lb	9.34	6.04	4.25	4.15
Weight of water at 400 lb per sq ft of heating surface, lb	3.52	1.61	0.96	0.69
Weight of water and steel per sq ft of heating surface, lb	12.86	7.65	5.21	4.84

Fig. 4 shows the 2-in-tube header-type boiler that was installed in many of the merchant-marine ships built during the last war, these being known as the "535's" or "State Ships." These boilers were designed to operate at 265 psi, with approximately 50 deg superheat in the steam at the superheater outlet, the superheater being located at the top of the first and second passes of the boiler. The weight per square foot of boiler heating surface of one of these units is 26 lb and the weight per pound of equivalent evaporation at full power is 4.7 lb, both of these being on the assumption that the boiler was under steaming conditions with water at the center of the gage glass. It will be noted how appreciable is the reduction in weight in going from the 4-in-tube boiler to the 2-in-tube construction, all other essentials of the unit, such as rating, location and type of superheater, setting height, etc., remaining approximately the same for both installations.

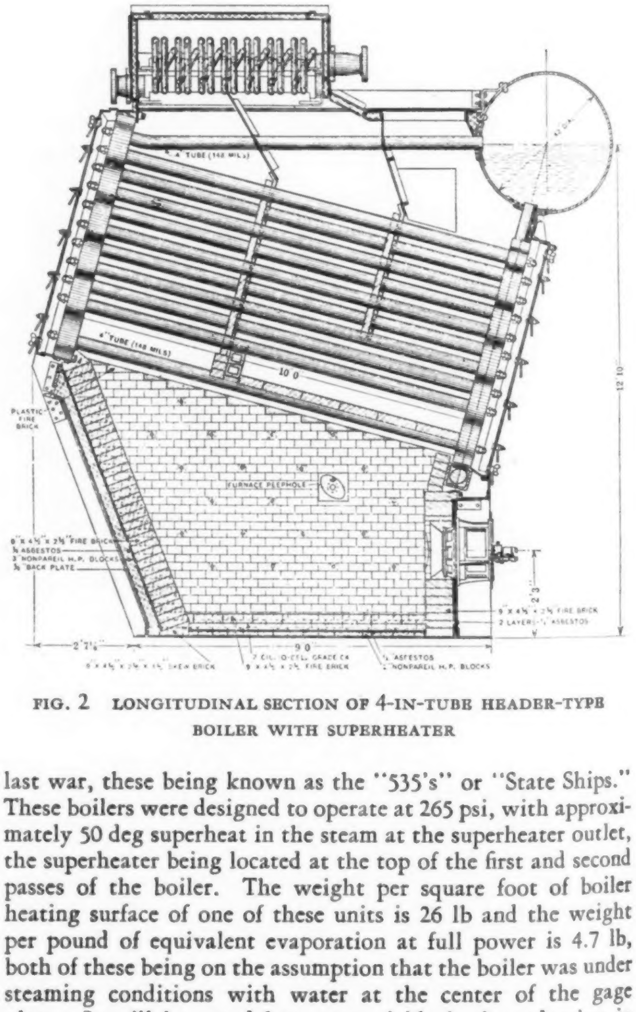

FIG. 2 LONGITUDINAL SECTION OF 4-IN-TUBE HEADER-TYPE BOILER WITH SUPERHEATER

When it became desirable to build new steam-driven tonnage in the 1920's, more attention was given to operating economy, which resulted in higher steam pressures and temperatures (up to this time 300 psi pressure and 75 F superheat

were the highest values used) and in the more general application of supplementary heat-absorbing equipment, such as air heaters. Fig. 5 shows a typical three-pass header-type boiler of this era as used in the merchant marine, the steam pressure being 400 psi, and the steam temperature 650 F. Tubes of 2 in. diam were still used for the boiler generating surfaces, but to obtain the higher steam temperature which was desirable with the higher steam pressure, the superheater was moved from the overdeck position at the top of the first and second

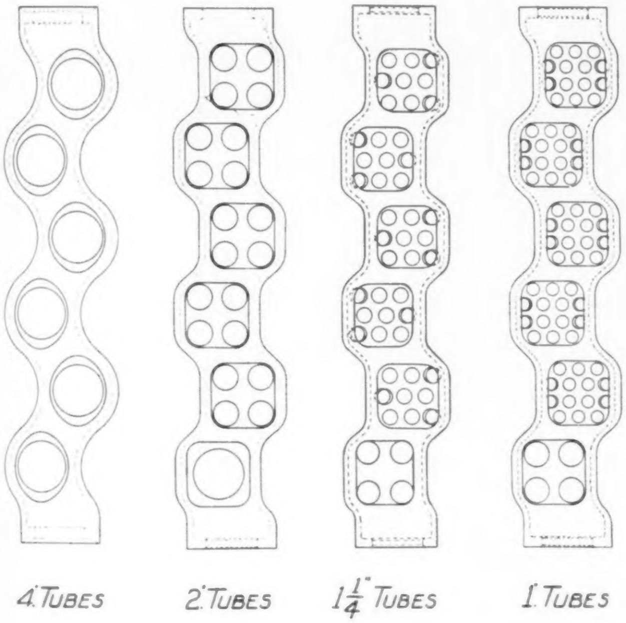

FIG. 3 TUBE GROUPINGS USED IN HEADER-TYPE-BOILERS

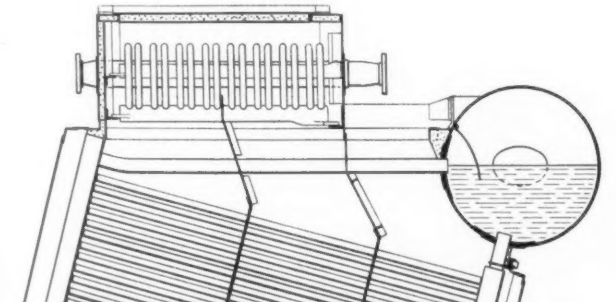

FIG. 4 LONGITUDINAL SECTION OF 2-IN-TUBE HEADER-TYPE MARINE BOILER WITH SUPERHEATER

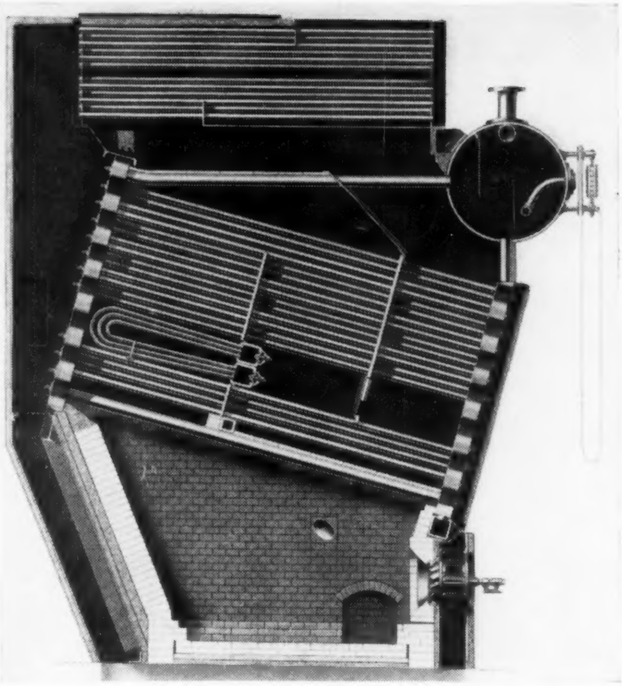

FIG. 5 LONGITUDINAL SECTION OF 2-IN-TUBE HEADER-TYPE BOILER WITH INTERDECK SUPERHEATER AND AIR HEATER

passes to an interdeck position in the first pass, where the products of combustion were hot enough to give the desired steam temperature with a superheater of moderate size. The horizontal-tube air heater had the air flowing through the tubes, the products of combustion flowing three times across the outside of the tubes. Boiler units of this type, complete with air heater, and with water, weigh approximately 40 lb per sq ft of boiler heating surface, and the corresponding weight per pound of equivalent evaporation at full power is 7 lb.

Single-Pass Header-Type Boilers

The increased use of cracked oil residue as fuel led to combustible and corrosive deposits lodging on any shelves which existed in the gas stream. Thus it became desirable to eliminate, as far as possible, such ledges where deposits could lodge. This, together with the saving in weight involved, led to the use of the single-pass type of header boiler, using tubes $1^1/_4$ or 1 in. diam, grouped as indicated in Fig. 3. Because of the improvement which had taken place in the art of feedwater conditioning, the use of tubes smaller in diameter than 2 in. was entirely feasible.

Fig. 6 shows the longitudinal and front-view sections of a single-pass header-type oil-burning boiler fitted with $1^1/_4$-in. tubes, interdeck superheater, and air heater, designed for operation at 625 psi pressure, and 900 F total steam temperature. Units of this general type have been extensively installed in modern tankers and in cargo ships built and building for the United States Maritime Commission. The front-view section clearly illustrates the stud-tube construction of the water-cooled side walls of the furnace, and the design and method of supporting the superheater tubes with $3^1/_4$-in-diam boiler tubes. To assure a constant steam temperature of approximately 900 F at the superheater outlet under all normal rates of operation, automatic superheat control is employed with this unit, utilizing an attemperator or desuperheater of the submerged-coil type, located in the steam drum as shown. The wet weight of this type of $1^1/_4$-in-tube boiler unit is approxi-

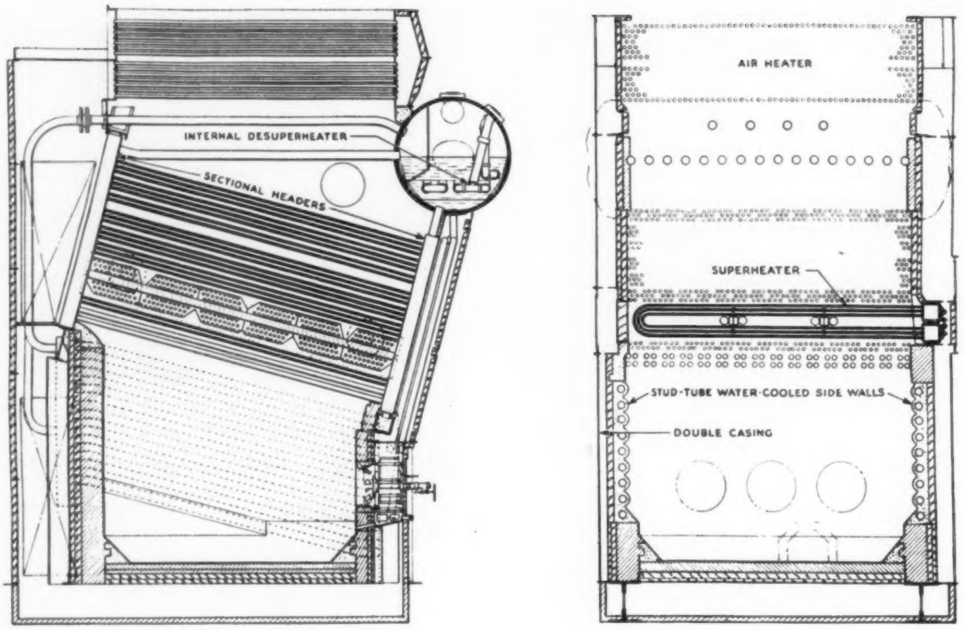

FIG. 6 LONGITUDINAL AND FRONT-VIEW SECTIONS OF $1^1/_4$-IN-TUBE SINGLE-PASS HEADER-TYPE BOILER WITH INTERDECK SUPERHEATER AND AIR HEATER

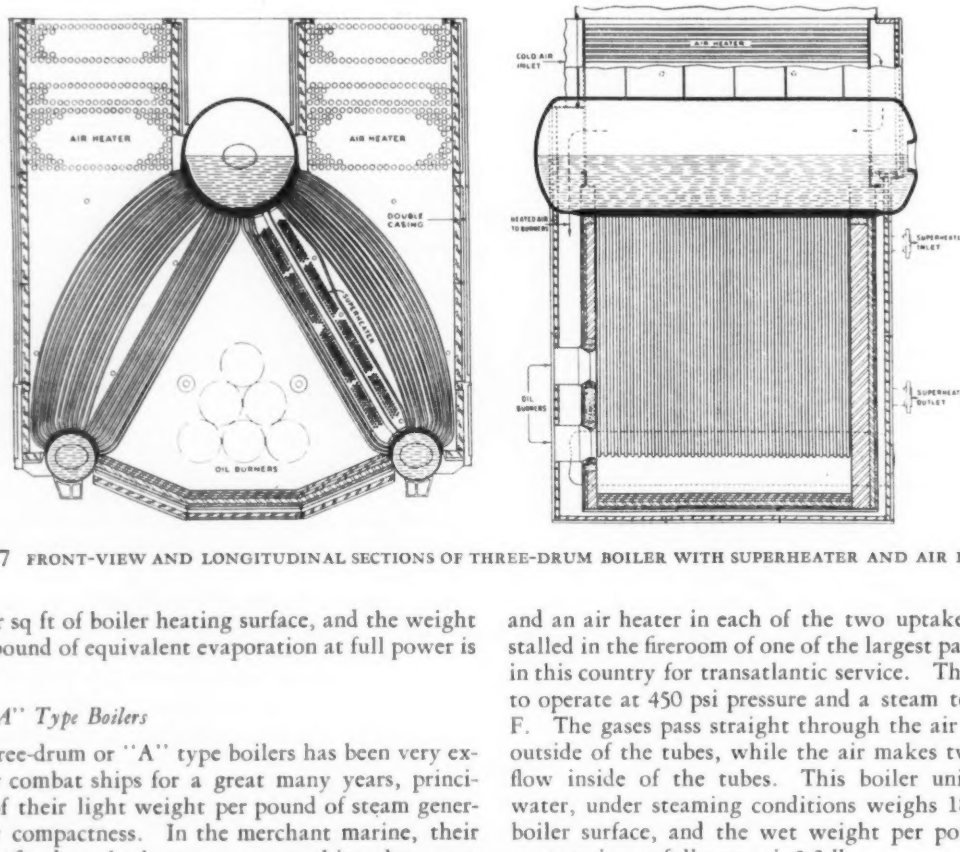

FIG. 7 FRONT-VIEW AND LONGITUDINAL SECTIONS OF THREE-DRUM BOILER WITH SUPERHEATER AND AIR HEATER

mately 38 lb per sq ft of boiler heating surface, and the weight of the unit per pound of equivalent evaporation at full power is 4.5 lb.

Three-Drum or "A" Type Boilers

The use of three-drum or "A" type boilers has been very extensive in Navy combat ships for a great many years, principally because of their light weight per pound of steam generated, and their compactness. In the merchant marine, their use has been confined to the larger passenger ships almost exclusively, because of the fact that relatively large steam demands per boiler are desirable to justify the use of boilers of this type, compared to the header or two-drum designs. Fig. 7 shows the front-view section of a double air-cased three-drum oil-burning boiler, fitted with a superheater in one bank and an air heater in each of the two uptakes, which was installed in the fireroom of one of the largest passenger ships built in this country for transatlantic service. This unit is designed to operate at 450 psi pressure and a steam temperature of 725 F. The gases pass straight through the air heater, across the outside of the tubes, while the air makes two passes counterflow inside of the tubes. This boiler unit complete, with water, under steaming conditions weighs 18.5 lb per sq ft of boiler surface, and the wet weight per pound of equivalent evaporation at full power is 3.2 lb.

At this point it may be of interest to note that three-drum boilers fitted with economizers, as used in Navy combat ships, are operated at appreciably higher rates under full-power conditions than is customary when using similar types of boilers in the merchant marine, the Navy ratings being anywhere from

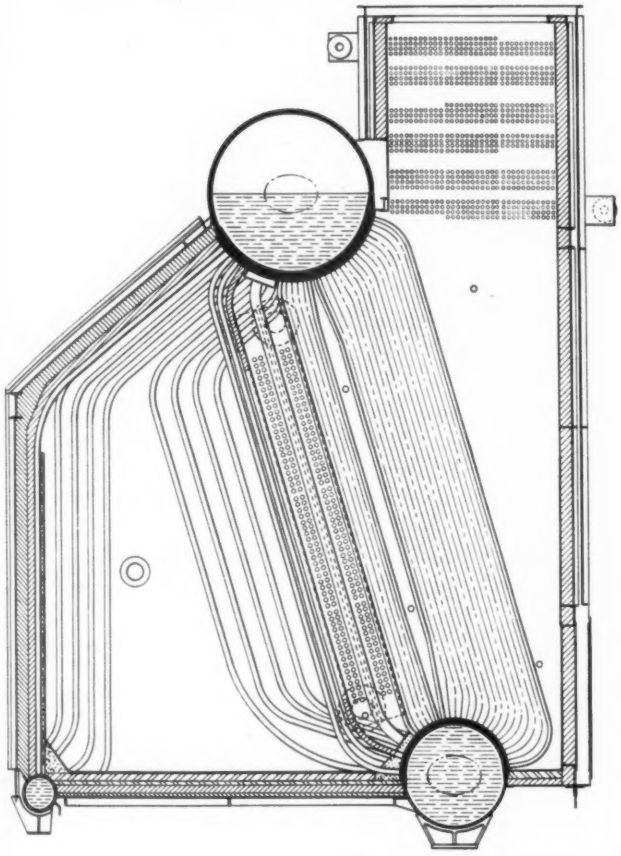

FIG. 8 FRONT-VIEW SECTION OF TWO-DRUM BOILER WITH SUPERHEATER AND ECONOMIZER

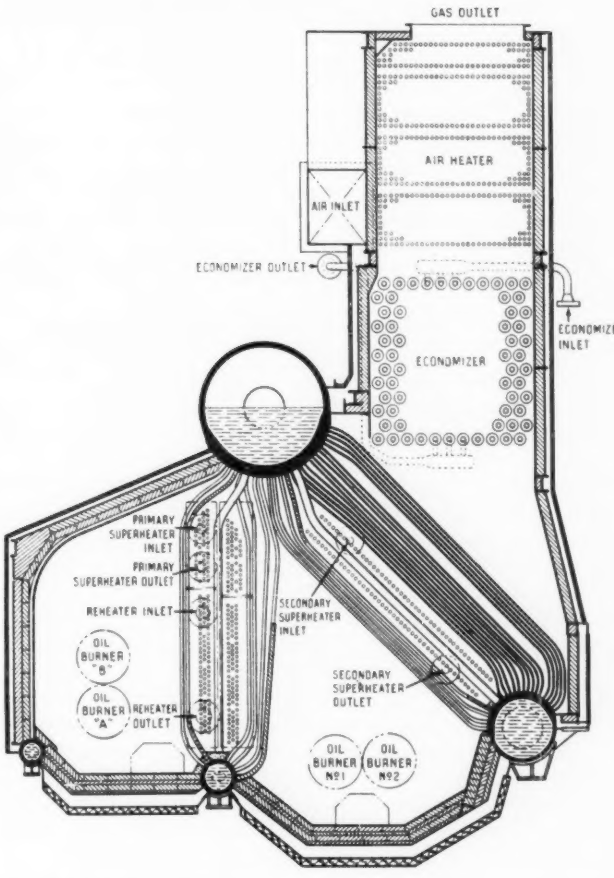

FIG. 9 FRONT-VIEW SECTION OF 2-FURNACE SINGLE-UPTAKE HIGH-PRESSURE REHEAT BOILER WITH ECONOMIZER AND AIR HEATER

3 to 5 times as great per square foot of boiler heating surface. Accordingly, although the steaming weight of a modern Navy boiler unit usually averages between 20 and 25 lb per sq ft of boiler heating surface, the corresponding weight of one of these units per pound of equivalent steam generated at full power is usually between 0.75 and 0.9 lb. Boilers in the merchant marine are usually designed to generate from 6 to 10 lb of equivalent steam per square foot of boiler heating surface per hour at the full-power condition, whereas, in Navy combat ships, the corresponding generating range at full power is in the neighborhood of 30 to 35 lb. In a somewhat similar manner, the Btu release rate in the furnaces of the merchant-marine boilers is usually between 75,000 and 110,000 Btu per hr per cu ft, whereas, in modern Navy combat ships, the full-power designed condition usually calls for a release per cubic foot of furnace volume of between 250,000 and 300,000 Btu. From the foregoing, it may be noted that the difference in weight of three-drum boiler units, as used in the merchant marine compared to Navy combat ships, is largely a matter of difference in rating employed when doing full power, rather than a difference in details of construction of the units.

Two-Drum Boilers

The use of two-drum boilers has shown an increase in the merchant-marine field the last few years, their relatively light weight and low cost being important factors in their favor for installation in ships of moderate power, in spite of their comparative inaccessibility for quick internal cleaning and repairing. To do any such work on boilers of this type, it is generally necessary for a man to enter the steam drum, and it usually takes an appreciable time interval for such a drum to cool sufficiently to permit this. If a ship has only two boilers and is on a fairly quick turnaround schedule, excellent care should be taken of boilers of the two-drum type, to avoid the possibility of tube losses or the necessity for frequent internal cleanings.

Fig. 8 shows a two-drum inclined-tube-bank marine boiler fitted with superheater and economizer, as installed in some of the modern merchant ships. There are no gas baffles whatever in this unit, the gases flowing horizontally through the water screen, superheater, and the boiler bank, then turning vertically upward through the economizer. The side wall of the furnace is fully water-cooled by means of stud tubes, while the front and rear walls have partial cooling by means of 2-in. bare tubes in front of regular refractory linings. The unit shown is designed to operate at 450 psi pressure and 750 F total steam temperature. The wet weight of one of these units per square foot of boiler heating surface is 25 lb, and the weight per pound of equivalent evaporation at full power is 2.7 lb.

Steam-Temperature Control

As the steam temperatures have increased in marine service, proper control of these temperatures has become more desirable, and in some cases essential. When maneuvering a ship which is not fitted with means for controlling the steam temperature, relatively wide fluctuations are liable to occur because of the rapid changes in firing rate. Another reason for the increasing application of means for controlling steam temperatures afloat is that, in geared-turbine installations, designed for high steam temperatures, it is usually customary to lower this tempera-

ture to the zone of 700 to 750 F when admitting steam to the backing turbines.

Steam temperatures have been controlled in marine installations by the various methods familiar in stationary practice such as (*a*) dampers so located in the gas stream that their movement diverts more or less of the gases over the superheating surfaces; (*b*) attemperators or desuperheaters located in the steam path approximately half way through the superheating surfaces, and (*c*) controlling the percentage of the gases flowing over the superheating surfaces by varying the quantities of the fuel fired in the two furnaces of a "divided-furnace" boiler.

An interesting application of the (*c*) method of steam-temperature control is illustrated in Fig. 9. This unit is employed to deliver steam to a turbine using a reheat cycle, the operating steam pressure in the boiler drum being 1270 psi, and the temperature of both the high-pressure and reheat steam being approximately 750 F.

Under "ahead" operating conditions, the saturated high-pressure steam enters the primary superheater, crosses over to the secondary superheater, and then passes to the high-pressure turbine. The steam from the turbine is sent through the reheater to bring its temperature back to 750 F, after which it is returned to the low-pressure stages of the turbine. When using the astern turbine, there is no steam to the reheater, so the burners on that side of the boiler unit are shut off, and all the steam necessary for backing is obtained by firing the fuel in the furnace under the secondary superheater. When operating under full-power-astern conditions, the oil burned on that side of the unit is appreciably greater than is burned there when going full power ahead, with the result that the temperature of the steam heated in the secondary superheater alone, under these conditions, is approximately 750 F.

FIG. 10 CYCLONE STEAM SEPARATOR

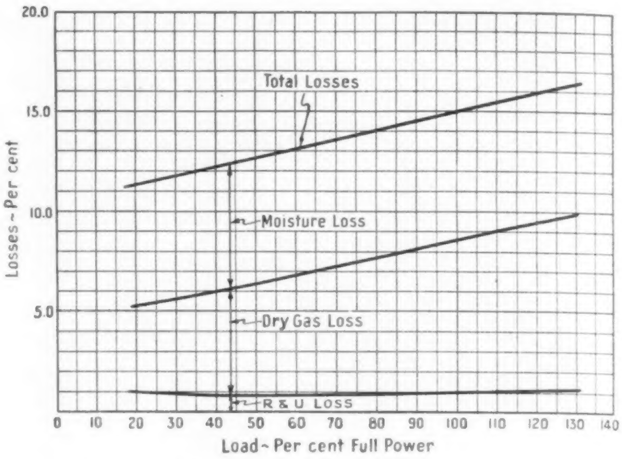

FIG. 11 CURVES SHOWING TYPICAL LOSSES TO BE EXPECTED FROM COMBUSTION OF OIL UNDER MARINE BOILERS

The boiler is provided with a complete double air casing. The section of this casing at the boiler front is subdivided by a partition from top to bottom, so that the burners for the reheat furnace are isolated from the burners for the other furnace. The oil burners are fitted with wide-range atomizers of the plunger type, automatically controlled to the reheat furnace, in order to maintain a constant temperature of 750 F in the reheat steam, and to the other furnace, to maintain the proper operating steam pressure.

Because of the relatively small proportion of boiler generating surface in this unit, and the required strength of the pressure parts, the steaming weight per square foot of boiler surface is 72 lb. The weight per pound of equivalent evaporation at full power is 5 lb. This installation emphasizes the fact that as the pressures, temperatures, and boiler efficiencies have been increasing, the weights per square foot of boiler surface have risen steadily, because the percentage of boiler generating surface grew appreciably less compared to the total surface in the unit. The weight of unit per pound of equivalent steam generated has, if anything, been gradually reduced, and this weight of boiler unit per pound of equivalent steam generated is the important one in designing a ship.

QUALITY OF STEAM

One of the important developments that has kept pace with the increasing steam pressures and boiler ratings has been the improvement in the quality of steam coming from the boiler drums. Improved steam-drum baffling has made possible the strides that have taken place in other directions in the development of marine boilers. This is done with plate baffling, sometimes submerged and sometimes in the steam space, or by means of centrifugal separators. Fig. 10 illustrates a baffle of the latter type which is finding wide application in the marine field at the present time, especially in ships that are designed to employ high boiler ratings at full power. This construction has assured remarkably dry steam with relatively high boiler-water concentrations over wide ranges of water level in the steam drum, an extremely important item when a ship is rolling or pitching in a seaway.

OIL BURNERS

When oil is used as a fuel under marine boilers, it is usually discharged into the furnaces in the form of a fine conical spray from one or more mechanical atomizers located in the center of circular oil-burner registers. Steam atomizing is not used to any extent in marine work at the present time because of the loss of fresh water its use entails.

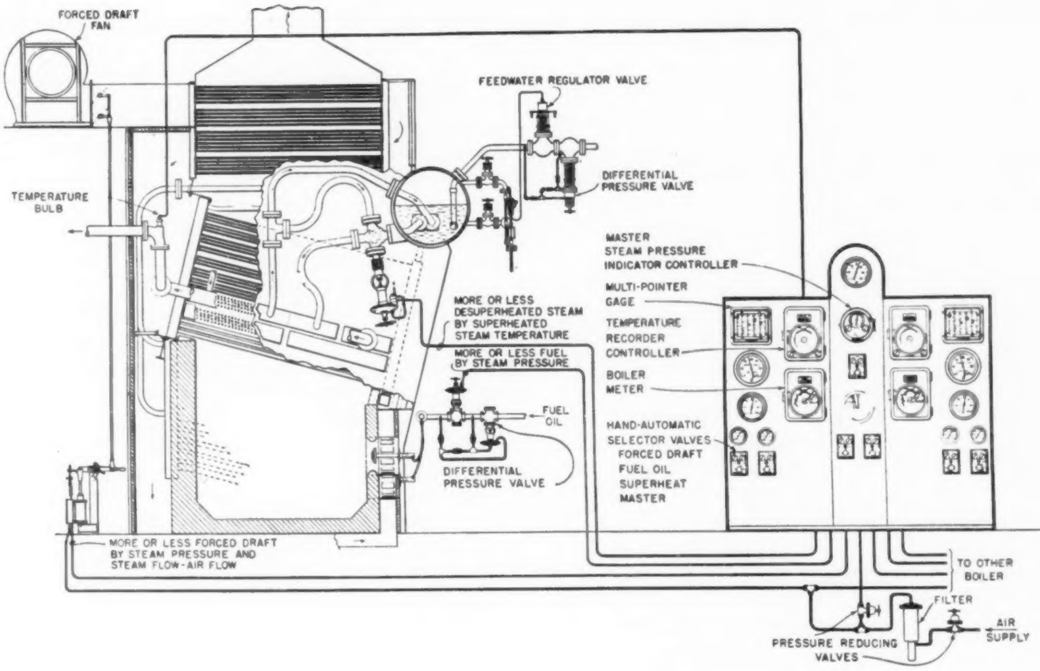

FIG. 12 DIAGRAMMATIC AUTOMATIC COMBUSTION AND SUPERHEAT CONTROL

Because of the limited operating range possible with atomizers of the standard mechanical type (approximately 2 to 1, without shutting off burners), there is a growing demand for atomizers which have wider-operating-range characteristics. There are now on the market several wide-range mechanical atomizers such as those of the return-flow type or those of the plunger type, which are being installed aboard ships to an increasing extent, especially where automatic combustion control is employed.

Fig. 11 shows in curve form the typical losses to be expected from an efficiently handled oil-fired marine boiler. Where the total losses are 15 per cent, the boiler efficiency would be 85 per cent. These curves show that the percentage moisture loss and percentage radiation and unaccounted-for loss are fairly constant over a relatively wide range of operation, the major cause of increasing uptake losses with increasing boiler ratings being in the heat carried away in the dry gases.

SOOT BLOWERS

Keeping the external surfaces of a boiler unit clean is essential if consistently high efficiency results are to be secured. Originally, the only method used for cleaning the external surfaces of a boiler unit was hand lancing with steam. Today, it is very exceptional to install a boiler unit in a ship without equipping it with automatic soot blowers.

The use of steam for soot blowing naturally causes an appreciable loss of fresh water from the ship's supply. To eliminate this loss automatic soot blowers using compressed air have been developed and are being increasingly applied in modern steam-driven tonnage.

AUTOMATIC CONTROLS

Feedwater Regulators

Feedwater regulators are almost universally used in modern merchant-marine installations. During the era of moderate steam pressures, regulators actuated by floats in the steam drum were frequently employed, but with the advent of pressures between 400 and 600 psi, this type is seldom used, the therom-hydraulic type being more generally accepted for this duty. In Fig. 12 is shown a typical regulator of this design, attached to a boiler drum.

In order to secure the most satisfactory results from any type of automatic feedwater regulator, a differential valve should be placed in the water line ahead of the regulator valve, as shown in Fig. 12, to maintain a constant pressure differential across the regulator valve, regardless of fluctuations that may occur in the steam pressure or in the water at the feed-pump discharge. This is to insure consistent water flow to the boiler at all times, for a given position of the regulator valve. If this is not done, relatively wide fluctuations in water level may occur in the boiler drum.

Combustion Control

Until a few years ago, automatic combustion control was seldom used aboard ship, but during the last few years, with a wider appreciation of its advantages and with direct savings in assuring consistent combustion efficiency, its application in modern steam tonnage of the merchant marine is almost universal. Fig. 12 shows the essentials of such an installation. The steam pressure is maintained at its desired value by the master steam-pressure indicator-controller actuating the equipment controlling the air supply from the forced-draft fan and the oil supply to the burners. The control of the air supply to the unit may be had either by the use of dampers, as shown in Fig. 12, or by directly controlling the speed of the fan, or both.

Superheat Control

Fig. 12 also shows a method of automatic superheat control which has proved very satisfactory in marine service. All the steam from the steam drum enters the superheater at the upper end of the top box and, after making three passes through the first half of the superheater, is taken either to the attemperator in the steam drum or directly back to the fourth

pass of the superheater, the quantity of steam going to each being controlled by the position of the three-way valve attached to the boiler drum as shown. The steam that goes through the attemperator returns to the three-way valve, joining the steam that was not desuperheated, the mixture going through the remaining three passes in the last half of the superheater. A temperature bulb is located in the steam piping from the superheater, this bulb serving to actuate the position of the three-way valve by means of the temperature-recorder (or indicator) controller.

If the steam temperature is controlled by means of dampers located in the gas stream, then they are actuated by means of the temperature-recorder (or indicator) controller in a manner similar to that shown for controlling the position of the three-way valve in Fig. 12. In the case of automatic steam-temperature control, applied to divided-furnace boilers, the air and oil supply to the burners on the superheater side of the unit are actuated by a temperature-recorder (or indicator) controller, while the air and oil to the burners under the saturated side of the boiler are actuated by the master steam-pressure indicator controller.

For an installation as shown in Fig. 12, filtered compressed air at approximately 35 psi pressure is the medium used to actuate the differential oil valves, three-way steam valves, and air-control-damper mechanism, under the direction of the controllers located on the central control board.

SYSTEMS FOR SUPPLYING COMBUSTION AIR TO MARINE BOILERS

Fig. 13 shows six methods that have been used to supply combustion air to marine boilers. Natural draft (*a*) is seldom used in modern ships, because of the impossibility of securing sufficient boiler rating with it, unless excessively high funnels are used. When natural draft was found too limited, the next step was to use the "double-front forced-draft" construction (*b*), the blower providing sufficient air pressure to overcome the resistance through the oil burners or bed of coal on the grates, the natural draft of the funnel being more than ample to take care of the gas resistance through the boiler unit, leaving a slight suction in the furnace.

Some induced-draft, (*c*) installations were made, but this method of supplying combustion air was never extensively employed, as the volume of gases handled by the fan was nearly double that of the atmospheric air supplied to the unit, requiring increased fan power. Also, because of the hot gases, the fan bearings had to be water-cooled, an awkward complication in a piece of auxiliary equipment located at the top of the boiler room of a ship.

The closed-fireroom forced-draft (*d*) type of installation was extensively used in the older Navy combat ships and in a few merchant-marine installations, where boiler ratings in excess of those possible with the double-front forced-draft (*b*) construction were required. Because of the hazards to the personnel involved in case of a gas attack, and the complication of the air locks, this systeam of supplying combustion air to the boilers is no longer being installed in ships of either the Navy or merchant marine.

The double-cased forced-draft (*e*) type of installation is the most generally used method of supplying combustion air to boilers in modern ships of both the Navy and merchant marine. It permits high boiler ratings without the possibility of the gases of combustion leaking into the firerooms, and at the same time allows the use of "open" firerooms; i.e., without

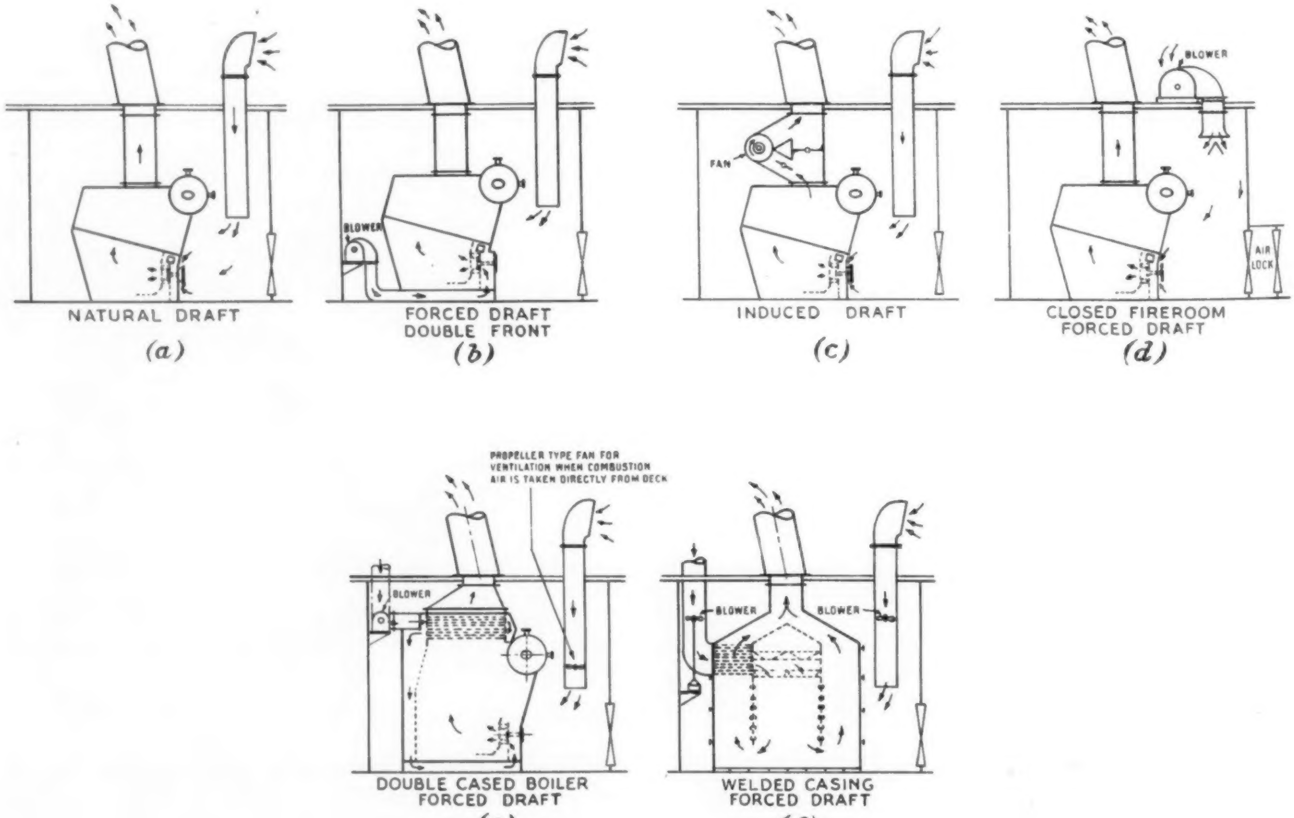

FIG. 13 DIAGRAMS ILLUSTRATING VARIOUS METHODS OF SUPPLYING COMBUSTION AIR TO MARINE BOILERS

air locks. The fan supplying ventilation air may be shut down during gas attacks.

The single welded-casing (*f*) installation may be operated at high rates without the possibility of gases leaking into the fireroom. This makes the lightest and most compact casing for use on boilers to be operated at high rates in an "open" fireroom.

TREND

The trend that has been taking place in the distribution of heat absorbed in marine-boiler units, as steam pressures and temperatures increased is illustrated in Fig. 14, which graphically compares the boiler unit shown in Fig. 2, which was installed in the ships of the Emergency Fleet during the 1918–1919 period and operates at 200 psi pressure and 50 F superheat, with the modern high-pressure (1270-psi) reheat unit, shown in Fig. 9. The percentage of the heat absorbed by furnace radia-

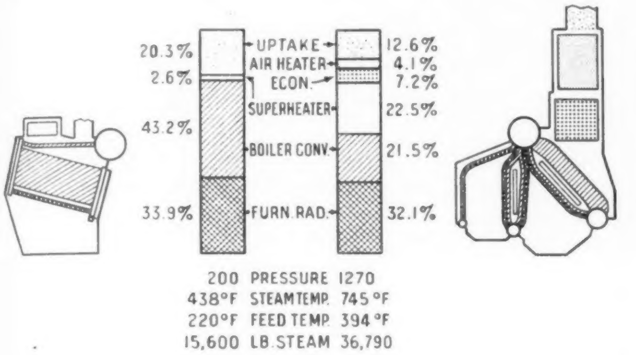

FIG. 14 DIAGRAM SHOWING DISTRIBUTION OF HEAT ABSORPTION IN VARIOUS PORTIONS OF BOILER UNITS, AS SHOWN IN FIG. 2 AND FIG. 9, RESPECTIVELY

tion remains about the same for both units, but the heat absorbed in the boiler-tube banks of the modern unit is only one half of that absorbed in the boiler-tube bank of the low-pressure unit. The percentage of the heat absorbed in the superheater of the modern unit is nearly nine times greater than that in the older installation. The economizer and air heater in the high-pressure unit are responsible for giving it an efficiency approximately 8 per cent higher than that of the older unit, with both operating at designed full power. Reference to Table 2 shows how this trend in boiler-unit design has been keeping pace with the change that occurs in the thermal characteristics of steam, in going from the lower pressures and temperatures to the higher pressures and temperatures.

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FISCAL POLICY AND BUSINESS CYCLES[1]

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THE high level of economic activity associated with the present war effort has not been particularly reassuring to the business community. Most businessmen are well aware that the defense program has done no more than postpone most of the difficulties with which they previously were faced, and they expect that, at the end of the war, conditions will again be as bad or worse than before. Farsighted business leaders have recognized for some time that the problems with which they, as individuals, had to deal, had their origins in fundamental economic changes which were taking place throughout the world. In particular they have been concerned about the continued depression in America and the policies which have been pursued by the government in attempting to cope with it.

To all such persons Professor Hansen's latest book[2] is of the greatest importance. It presents, in easily understandable terms, an analysis of the economic situation of America in the thirties, and makes specific suggestions regarding future governmental policy. Professor Hansen's position as Littauer Professor of Political Economy at Harvard makes it evident that some weight can be attached to his economic analysis. Since he is not without influence in administrative circles, his views on policy ought likewise to be given very careful attention.

In the early years of the Great Depression few persons recognized that we were experiencing anything other than an ordinary cyclical phenomenon. As time went on, however, and recovery continued to be incomplete, it became clear that the situation was more serious than had at first been thought. Professor Hansen was one of the first to put forward the thesis which has come to be known as the secular stagnation hypothesis. The thesis was developed in his "Full Recovery or Stagnation," and it plays an important part in the present work. According to this view the high levels of economic activity achieved during the nineteenth and early twentieth centuries are to be accounted for in terms of the wide range of private-investment opportunities maintained not only by a continuous flow of new technological developments, but by a high rate of population growth and exploitation of new resources as well. The large volume of savings made during these years gave rise to no serious difficulties, since there were always ample uses for them in the financing of business expansion. More recently, however, opportunities for continued private investment have become increasingly limited. Not only have our own natural resources been largely exploited, but opportunities for investment abroad have become scarce, and rates of population growth have begun to decline. These are changes of a fundamental character, and their significance lies in the fact that investment opportunities are coming to be limited to those made available by the progress of scientific research. With fields for large-scale new investment thus limited, it is no longer possible to find uses for all the savings which continue to accumulate. Hence, saving may merely withdraw funds from the monetary stream without replacing them by government spending, and the level of the national income may remain indefinitely below that necessary to maximum output and full employment in the economy.

If this diagnosis of our economic ills is correct, the question arises as to what, if anything, can be done about it. One obvious answer is that nothing really needs to be done. This is, in fact, a position which many businessmen have been inclined to take. Even assuming that the secular stagnation hypothesis has some validity, it is possible to argue that intensive investment would be more than sufficient to absorb the community's savings if profit opportunities were not curtailed by governmental policies that remove incentives to invest. Though this view is in some respects tenable, it lacks a good deal of being thoroughly realistic. It must be recognized that the increasingly important role which government has recently come to play in economic life has been largely the unplanned result of a series of expedients adopted to meet the problems of severe depression. The problems were too pressing to be ignored, and attempts to deal with them must inevitably have led to a considerable extension of governmental activities and controls. If many public policies tended to retard recovery, it is also true that much governmental activity could not be brought to an end until higher levels of employment had been achieved. Simply to complain now that something different might have been done years ago is hardly an adequate substitute for thought. A return to the past is impossible, and in so far as individuals are powerless to control the course of events they should seek to understand and adjust themselves to them. Since the role of government is likely, as a result of the war, to become more than ever important in this country, Professor Hansen's proposals cannot wisely be disregarded.

Under present conditions, he believes, private investment is unlikely to absorb savings and make possible full use of our resources. Savings are not likely to fall to a much lower level since they are determined largely by institutional factors, and consumption, therefore, cannot be relied upon to increase sufficiently to produce anything like full employment. The only way to fill the gap between consumption and full-employment income, formerly occupied by private investment, is with public expenditures supported by deficit financing and taxation.

Professor Hansen's suggestions cannot be treated here in detail; even the foregoing summary of his principal thesis hardly does justice to his views. Only his book can well do that, and it is hoped that every reader of this review will read "Fiscal Policy and Business Cycles."

Professor Hansen's style is clear and he possesses an ability to make difficult subjects readily understandable. Especially recommended is his chapter called "The Growth and Role of Public Debt" which deals with the place of the federal budget in our economy, and with the puzzling question of the limits to the size of the public debt. These are matters concerning which there is much confusion, and Professor Hansen's discussion will clarify the issues even for those who find themselves in disagreement with some of his conclusions. This statement is true of much of the remainder of the book. Professor Hansen is discussing controversial subjects, and his views are necessarily open to objections. No one, however, can claim to possess an intelligent opinion one way or the other who has not considered carefully the arguments Professor Hansen presents.

[1] One of a series of reviews of current economic literature affecting engineering prepared by members of the department of economics and social science, Massachusetts Institute of Technology, at the request of the Management Division of The American Society of Mechanical Engineers. Opinions expressed are those of the reviewer.

[2] "Fiscal Policy and Business Cycles," by Alvin H. Hansen, W. W. Norton & Company, Inc., New York, N. Y., 1941.

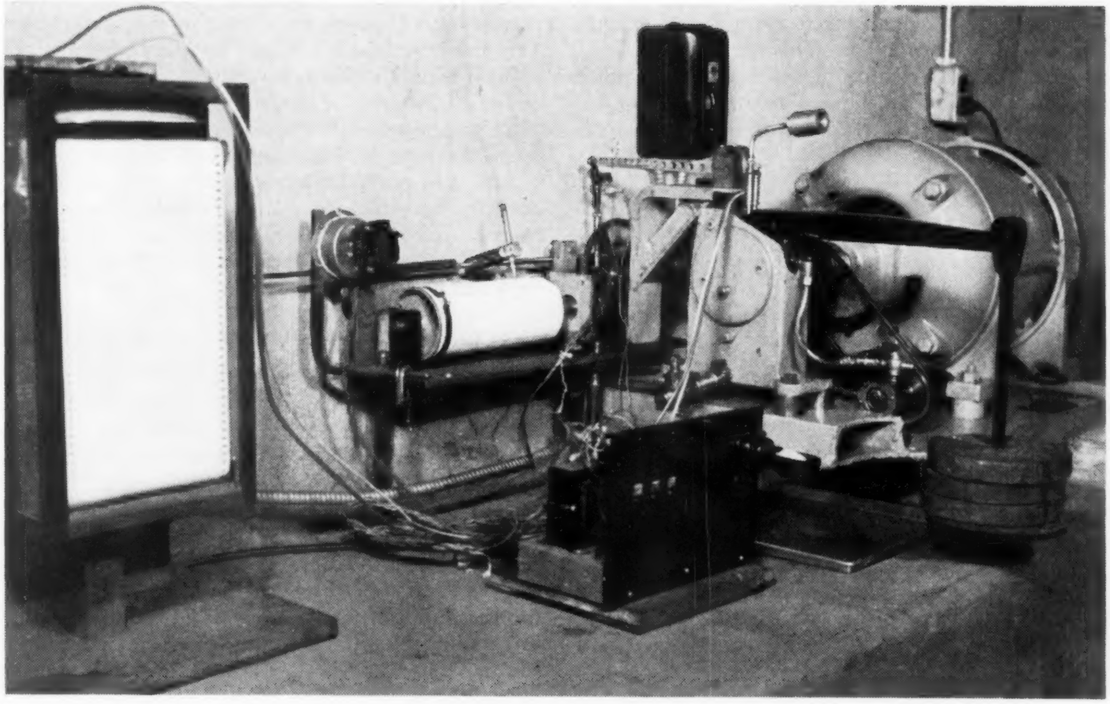

FIG. 1 AUTOMATIC AUTOGRAPHIC WEAR-MEASURING DEVICE

Automatic Autographic WEAR-MEASURING DEVICE

Apparatus for Measuring Displacement of Material During Wear Tests

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IN MAKING comparative wear tests of bearing materials under similar conditions of pressure, lubrication, velocity, surface finish, and other complex and numerous variables encountered in such tests, the amount of specimen material displaced by wear or plastic flow may be obtained by measuring the deflection of a combination loading arm and "wear" magnifying lever, or by removing the specimen from its holder and noting the change in thickness. Readings are taken at regular intervals of time to give one form of wear-time relationship. The author has developed an apparatus which automatically produces such a displacement-time diagram with results that vary from measured values by a maximum of 4 per cent.

HOW THE DEVICE FUNCTIONS

Bearing specimens 0.798 in. diam and $^1/_2$ in. long are held against a hardened-steel rotor by a loading arm.[1] As the bearing material is displaced, by contact with the turning rotor, the specimen moves downward, and the movement or amount of displacement is followed by two metal fingers which rest in holes drilled in the specimen. Inasmuch as the finger tips resting in the holes are only 0.08 in. from the test surface, any temperature change in the specimen is disregarded, since the expansion or contraction of such a short length is considered to be negligible. Further to minimize error because of temperature changes in the specimen, these fingers are made of Westinghouse Super-Invar alloy steel, having a linear coefficient of expansion of 0.7×10^{-6} in. per in. per deg C. A schematic diagram, showing the relationship of the specimen, measuring fingers, and other equipment, to the recording device is given in Fig. 2.

The fingers are attached to a lever arm by universal joints in such a manner that they are self-aligning, and measure the average displacement, in the event that one side of the specimen loses more material than the other. A counterweight permits the fingers to follow this displacement easily. The lever arm has a contact point on the end opposite the measuring

[1] The wear apparatus to which this device has been adapted by the author is similar to that described by J. R. Connelly, "A New Method of Investigating Performance of Bearing Metals," Trans. A.S.M.E., vol. 57, 1935, p. 35.

fingers. As the specimen and the fingers move downward, the contact is broken, actuating a relay. This relay starts a small Synchron clock-type motor which moves a recording pencil across the record chart (up on the ordinate), indicating displacement of bearing material. The recording pencil is con-

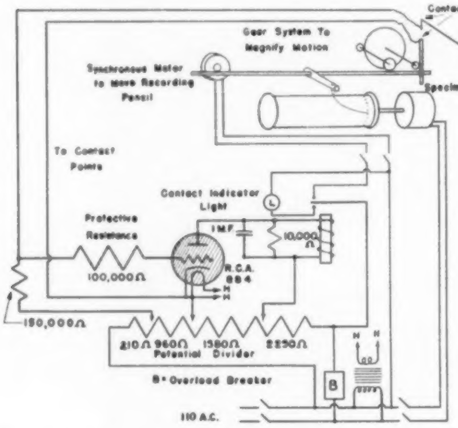

FIG. 2 SCHEMATIC DIAGRAM OF MEASURING APPARATUS AND WIRING DIAGRAM OF ELECTRICAL CIRCUITS

(Synchron motor on record drum, 1 rev per 12 hr.)

nected with a spur-gear magnification system and the lower contact point. Movement of the pencil thus raises the lower contact point, establishes contact again, and breaks the circuit. The "running-in" of the specimen continuously makes and breaks the relay circuit. The drum, which holds the record paper, is turned one revolution in 12 hours by another Synchron clock-type motor. The resulting record chart thus combines the two factors, material displacement and time, to produce a form of wear-time diagram. The lever arm on the fingers and the gearing system provide a magnification ratio of 500 to 1.

An RCA 884 Radiotron tube is used in the relay circuit across the contact points to prevent sparking and to permit the utmost sensitivity to change in the amount of specimen displacement. The wiring diagram for the tube and relay circuit is also shown in Fig. 2. A 7-w lamp placed across the contact points and actuated by the relay is used to make initial adjustments at the start of a test. The lower contact point is adjustable and is raised or lowered until the light indicates that the points are just at contact. The complete apparatus is shown in Fig. 1.

CALIBRATING THE APPARATUS

The device is calibrated by placing a feeler gage between the rotor and a specimen that has not been tested. The contact points are adjusted and the recording pencil set at zero. When the feeler gage is removed, contact is broken and the recording pencil moves across the diagram until contact is again established. The ratio of this movement to the thickness of the feeler gage is the magnification ratio of the instrument. The upper contact point may be moved nearer to or away from the lever-arm fulcrum to obtain the magnification ratio of 500 to 1. By this method, it has been found that the device responds readily to a specimen movement of 0.0001 in. This sensitivity is possible because of the Radiotron tube placed across the contact points.

The modified wear-time curves obtained automatically with this apparatus rise steeply during the first few hours of running-in, indicating rapid displacement of bearing material, and exhibit a reduced slope as the time of operation continues. Two representative curves are shown in Fig. 3. These curves are very similar to those obtained by other investigators using the manual methods already mentioned.

The contact area of the bearing sample is obtained by simple calculations, based on the displacement of material as obtained from the autographic diagram. This area may also be determined by removing the specimen from the loading arm and actually measuring the width of the displacement with a stage microscope. The areas calculated from the actual measurements vary from those obtained from the autographic diagram by a maximum of 4 per cent.

LIMITATIONS OF PERFORMANCE

This device will not measure any "negative wear" which may take place. In addition, extreme plastic deformation, which causes the bearing metal to flow and increase the specimen diameter, produces considerable error in determining the contact area from the autographic diagram. In this event, the diagram is used only to indicate whether the specimen is in the initial rapid stage of running-in or has reached a steady rate of material displacement. Variation in diameter of the hardened-steel rotor causes vibration across the contact points. By making the initial contact setting when the specimen rests on the low spot of the rotor, error due to vibration is minimized since the apparatus continues to measure this low spot. These vibrations, however, do prevent perfect initial setting of the

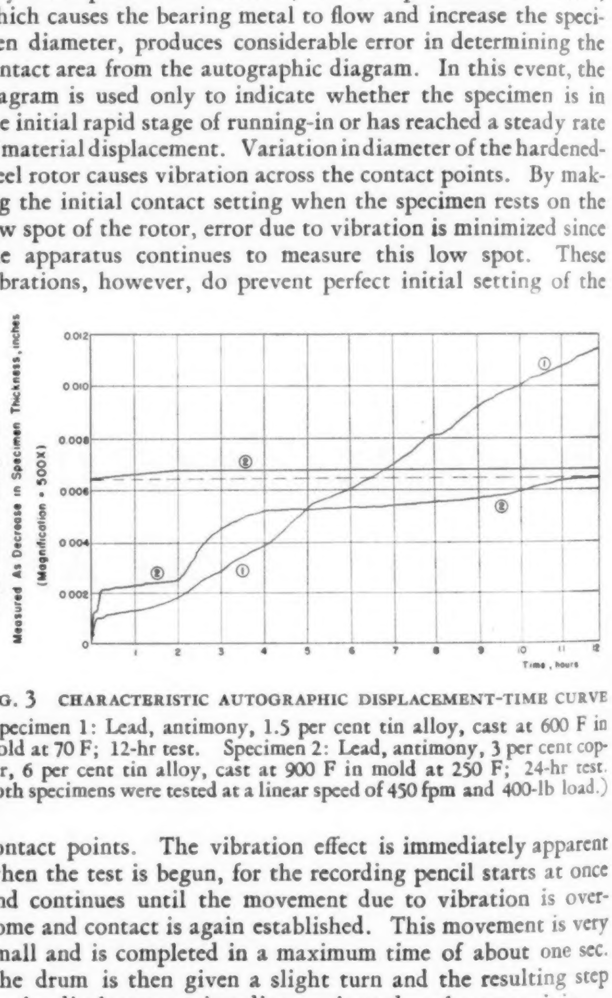

FIG. 3 CHARACTERISTIC AUTOGRAPHIC DISPLACEMENT-TIME CURVE

(Specimen 1: Lead, antimony, 1.5 per cent tin alloy, cast at 600 F in mold at 70 F; 12-hr test. Specimen 2: Lead, antimony, 3 per cent copper, 6 per cent tin alloy, cast at 900 F in mold at 250 F; 24-hr test. Both specimens were tested at a linear speed of 450 fpm and 400-lb load.)

contact points. The vibration effect is immediately apparent when the test is begun, for the recording pencil starts at once and continues until the movement due to vibration is overcome and contact is again established. This movement is very small and is completed in a maximum time of about one sec. The drum is then given a slight turn and the resulting step in the displacement-time diagram is used as the true origin.

The apparatus described may be used most effectively in that type of wear test where the specimen is permitted to adjust itself to some applied load under standard conditions of operation. Specimens may be of the relatively massive type, machined from castings, or they may be made with a facing layer as commonly used in bearing linings.

ACKNOWLEDGMENT

The author wishes to acknowledge the valuable assistance of Mr. A. M. Cadman of the A. W. Cadman Manufacturing Company, Pittsburgh, and Dr. B. R. Teare, Jr., professor in the department of electrical engineering of the Carnegie Institute of Technology, in developing this apparatus.

BETTER WAGE INDICES *for* METALWORKING PLANTS

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[The session at which the following paper was presented arose out of the suggestion, developed by the Work Standardization Committee of The American Society of Mechanical Engineers, that "there be available an index of wage rates to provide a factual basis for judging changes in prevailing wage rates, in much the same manner as the indices of cost of living, business conditions, etc., serve in their fields." Preparation of such an index of wage rates for any community or industry requires that means be provided for periodically collecting data on prevailing wage rates for a group of well-defined occupations, commonly prevalent in that community or industry, and that such data be given sound statistical analysis. It was suggested that such an index of wage rates could provide a better common factual basis for negotiations on questions of wage determination than was heretofore available.

The Work Standardization Session for the 1941 Annual Meeting was organized to:

1 Discuss the setting up of such an index of wage rates from the standpoint of the practical problems involved.

2 Discuss the desirability of such an index from the viewpoints of management, labor, and the public.

3 Decide, largely on the basis of these discussions, as to the advisability of proceeding further to develop such indices for practical use.]

IT WOULD be presumptuous in the extreme for the author to attempt to present a finished blueprint for the preparation and dissemination of improved wage indices. This paper represents merely a preliminary analysis of the problem and of the obstacles to be overcome, offered in the hope that it may set the stage for further study. This Society is ideally constituted to discover further refinements in wage indices for metal trades, because its membership includes many executives who specialize in building and operating machine tools.

Obviously, the first step is to state the objectives. One objective is to provide information that will reflect, quickly and accurately, changes in the wage-rate structure in each of the important labor markets from which metal plants draw their factory and clerical employees. A second objective is to reduce the cost in time and money of collecting and disseminating this information in order to lighten the burden on the co-operating firms.

The first of these objectives suggests the following questions:

1 What occupations that can be defined with sufficient precision, taking into account the factors influencing occupational difficulty that are common to the majority of metalworking plants, will provide an adequate sample of hourly rates, of incentive earnings, and of clerical salaries?

2 What range of skill and responsibility (e.g., from that of common labor to that of toolmaking) should the selected occupations cover?

3 Must such considerations as steadiness of work and overtime that affect annual earnings be disregarded?

The second objective, i.e., economy in the collection and dissemination of wage information, raises the following questions:

1 How small a number of common occupations would suffice for each type of rates (hourly, etc.)?

2 How large a sample of co-operating firms is required in each labor market to provide an adequate sample?

3 How frequently and expeditiously must the results be made available if they are to prove useful in wage negotiations, especially at a time when rates are changing rapidly?

WHAT OCCUPATIONS COMMON TO METAL PLANTS WOULD PROVE USEFUL?

Obviously, the occupations selected should meet the following tests:

1 The nature and difficulty of the work done must be susceptible of precise definition.

It is not hard to list the operations involved in the chosen occupations, the materials worked upon, and the machines and equipment used. To define the difficulty of the work, however, is truly perplexing.

The word "difficulty" encompasses skill in all its ramifications, as well as the responsibility for preventing damage to materials, product, or equipment. The question of skill cannot be disposed of properly by indicating the closest tolerance required. This tolerance may apply to a considerable portion of the jobs on which an employee is asked to work, or to only a small proportion of them. Moreover, the skill involved in meeting a certain tolerance is affected tremendously by the size of the part being machined; it increases when the parts are extremely large or small. Naturally, the amount of skill required is influenced also by the materials worked upon and the equipment used. Furthermore, the relation between the tolerance specified and the difficulty of obtaining it is not a simple one.

In addition to skill, the difficulty of an occupation includes fatigue. Like skill, fatigue defies precise measurement, especially under practical shop conditions.

2 The occupations selected should be those in which most of the reporting firms have a considerable number of employees. Preferably, the occupations chosen should be those for which an adequate sample of both hourly and incentive rates can be secured, not necessarily from each individual company but at least from the whole list of firms.

3 The occupations selected should vary in difficulty and be spread rather evenly over the entire range of skill and responsibility covered in the survey.

WHAT RANGE OF SKILL AND RESPONSIBILITY SHOULD THE SELECTED OCCUPATIONS COVER?

It is clear that the least skilled occupations in all the company divisions surveyed should be represented by at least one

Contributed by the Management Division and presented at the Annual Meeting, December 1–5, 1941, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

occupation. For factory employees, this might be common labor or janitor work (male). The least skilled of the clerical occupations might be represented by the work of office boys or office girls.

To choose occupations that will reflect work of the maximum difficulty surveyed presents a more difficult problem. For hourly workers in metal plants, one or more grades of toolmaker might be used. However, the skill required of toolmakers is influenced tremendously by the types of dies and jigs being made, by the diversity of work, the machine tools available to them, and the extent to which they are aided by blueprints and supervision. In the case of clerical employees, the occupation should be one, such as time-study analyst, in which the average firm employs more than one individual. Here again, the difficulties of definition are serious. Just as time-study analysts range from mere rate setters to industrial engineers who modify layout and process or suggest changes in design, so other highly paid clerical occupations, such as sales correspondent and secretary, differ greatly in the responsibility they carry and in the freedom of action allowed.

Having selected the common occupations at both extremes of the difficult range to be covered, the intervening occupations selected should be scattered over this range in order to avoid undue concentration at any one degree of difficulty or skill.

One of the practical problems to be faced in the selection of suitable occupations is the necessity to differentiate between incentive earnings per hour and hourly rates. A large proportion of companies have placed their productive occupations on incentive, but have kept their service occupations, such as those in the toolroom, on straight time work. This fact might necessitate the selection of a different group of occupations for the index of incentive earnings than for the index of day-work rates.

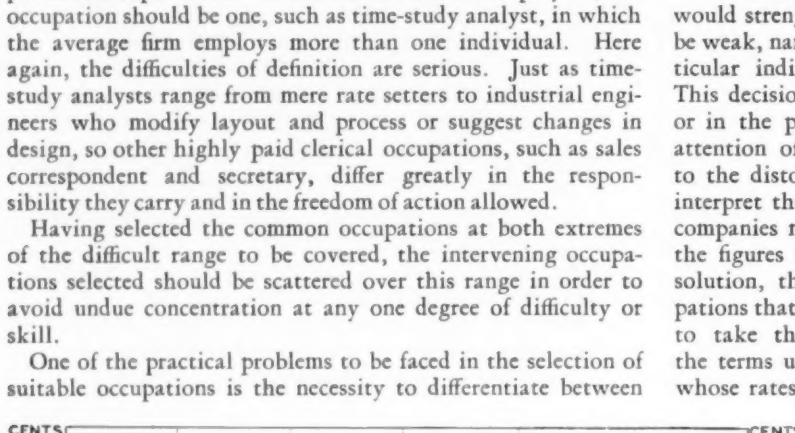


FIG. 1 HOURLY WAGE RATES IN PHILADELPHIA LABOR MARKET AND RATINGS OF RELATIVE DIFFICULTY OF SELECTED OCCUPATIONS

MUST CONSIDERATIONS THAT AFFECT ANNUAL EARNINGS BE DISREGARDED?

At certain times in the business cycle, employees are interested in the security of their jobs and pay, both of which are reflected in annual employee earnings. The attention paid to annual compensation is the product of the same forces that underlie the world-wide urge toward job security. This interest tends to mount in depression and to lag in prosperity.

Annual earnings, however, represent the product of hours worked and rates per hour. The latter are the center of interest in wage surveys, because, in wage setting, the rates paid to employees and the unit labor costs of the employer are the questions of immediate concern. Consequently, it would seem wise to confine wage surveys to rate information indicative of the prices of labor of given skills at a given time. After all, seasonal irregularity of work is likely to be reflected in the rates paid.

HOW SMALL A NUMBER OF COMMON OCCUPATIONS WOULD SUFFICE FOR EACH TYPE OF RATE?

It is the author's belief that a list of ten occupations might be adequate to reflect changes in hourly rates and incentive earnings for productive occupations; another ten for service occupations; and yet another ten for clerical jobs. Such a limited list would be practical only if the processes of the firms sampled were quite similar.

Moreover, this limitation of the number of occupations would strengthen present surveys at a point where they tend to be weak, namely, the decision in each company as to the particular individuals belonging in each occupation surveyed. This decision is frequently made by a clerk in the personnel or in the pay-roll department, whereas, it should have the attention of a major executive. Nothing contributes more to the distortion of wage-survey results than the failure to interpret the survey definitions correctly. If the co-operating companies misuse the definitions in the survey questionnaire, the figures collected must necessarily be faulty. A practical solution, therefore, is to use such a small number of occupations that a major executive of each company will be willing to take the time to translate the survey definitions into the terms used by his company, and to select the employees whose rates should be reported. Such managerial attention is possible with an index based upon a restricted list of occupations, and is unlikely with a long one.

It is not essential that all of the co-operating firms have employees in each one of the selected occupations, provided the sample of companies is sufficiently large. Moreover, the use of the survey results by a given company is not dependent upon whether or not that company has men in all the occupations surveyed. A systematic method of job evaluation will permit rate schedules to be adjusted upward or downward in accordance with changes in the market, as indicated by a few occupations, properly selected.

A firm can compute the line portraying the rates prevailing in a given market by determining the line of best fit for the averages of the survey occupations whose relative difficulty has been evaluated by that firm. The results may be shown in chart form by plotting the occupational averages above the points on the base line corresponding to the firm's own evaluation of the relative difficulty of these occupations, as indicated in Fig. 1.

HOW LARGE A SAMPLE OF COMPETING FIRMS IS REQUIRED IN EACH LABOR MARKET TO PROVIDE AN ADEQUATE SAMPLE?

Obviously, the larger the number of firms included, the more reliable the results. Both small and large, organized and unorganized, prosperous and unprosperous companies should be included. The sampling could scarcely be considered satisfactory for a given labor market as, for example, Cleveland, New York, or Philadelphia, unless the co-operating firms employed a substantial part of its metalworkers and unless the sample of firms were a random one.

If the sample of co-operating companies and of employees covered is large enough, the average rate for each selected occupation will reflect the amount paid for that kind of work. It is essential to distinguish between the work done and those who do it. The employees in a given occupation may be efficient or inefficient, and may have had short or long periods of

service, and the actual rates paid to them as individuals may reflect these factors. However, the rates of the employees in a given occupation at a given time do reflect the price paid for that kind of work, provided the sample is large enough so that differences in efficiency and workmanship average out.

HOW FREQUENTLY AND EXPEDITIOUSLY SHOULD THE RESULTS BE MADE AVAILABLE?

It would be highly desirable for the surveys to be made quarterly, or at least semiannually. In order that the results might be as timely as possible when used in wage negotiations, it is also important that they be collected and disseminated with dispatch. Possibly, the delay between the collection and the distribution of the figures should not exceed one month.

SUMMARY

The foregoing discussion of the objectives to be sought in setting up better wage indices may be summarized briefly:

The use of wage indices of the type contemplated in this paper should not be looked upon as a step toward a mechanistic approach to wage adjustments. Rather, such indices are necessary to provide the factual information without which management will be inadequately informed. Such data correspond to the price information so essential to the intelligent purchasing of raw materials. Moreover, their availability at the conference table, when management is discussing its wage policy or negotiating with employee or union representatives, will do much to make the discussion objective and realistic.

Views of Management, Labor, and Government

FOLLOWING Dean Balderston's paper, L. Clayton Hill's[1] paper, "Let Us Develop Wage Indices Realistically," was read by the recorder.[2] The high lights of Mr. Hill's paper were as follows:

MUST CONSIDER BARGAINING TABLE

One cannot underestimate the tremendous influence of bargaining-table discussions upon the setting of wage rates. In the past, the bargaining table has had some influence, but the tremendous advance of labor organization has elevated it (the bargaining table) to the dominating influence on wage determination. Those companies which do not set their wages around the collective-bargaining table must necessarily pattern them after wages which are so determined. For reasons of equity, salaries must move along with the hourly wages determined at the bargaining table.

Because of its tremendous influence, the bargaining table cannot be left out of the determination of any wage index or base. It is for this reason that attention should be called to the wage questions which are raised by employee representatives when they face management with 'more pay' demands in the bargaining conference.

The various approaches may be classified as follows:

1 Demands associated with company profits.

2 Demands based on wages paid by other companies for like work, or based on inequality between equivalent jobs within the plant.

3 Demands based on changes in cost of living. (In this connection Mr. Hill cited Harold F. Browne's paper[3] as giving a balanced discussion on the significance of cost of living indices.)

4 Demands based on sheer pressure.

5 Demands for concessions such as premiums for night work, rest periods, etc.

Mr. Hill concluded:

"That there is need for a more factual basis for collective bargaining, no one will deny. Almost any contribution to the problem based on accurate measurement will be helpful. The task is not an easy one and this paper is not intended to discourage those working on the problem. It is merely an attempt to face the task realistically, keeping in mind all the human relationships which so frequently are in conflict around the bargaining table.

[1] Vice-president and general manager, The Murray Corp. of America.
[2] Bernard Shereff, Industrial Engineer, American Hard Rubber Co.
[3] Management Record, National Industrial Conference Board, November, 1941.

"There will never be any substitute for the square deal between management and labor. Each must build confidence in the other's desire to do the fair thing. The all too obvious suspicion which has existed between employer and employee must be dispelled. If ever there was a pertinent application of the old adage, 'Acts speak louder than words,' it is in the field of industrial relations. The best wage index in the world will be valueless if complete confidence does not exist between management and labor. Let us continue our work on the development of a valuable wage index, but while doing so, let us create by our actions an atmosphere of confidence around the collective-bargaining table."

INDICES NOT SOLE DETERMINING FACTOR

Harold J. Ruttenberg[4] was the third speaker and spoke from the view of organized labor. The salient points of his presentation were as follows:

Organized labor believes in the establishment for each industry of a joint management-labor agency which will undertake, for all companies in the industry, to establish job specifications on a sound and uniform basis. Further, that such an agency collect factual data on wages and related matters within the industry.

"Wage structures," said Mr. Ruttenberg, "have heretofore been haphazard and this is why there has been such a large-scale turning, by employers, to job evaluation and merit rating with a view of finding a rational approach to the question of wages."

Mr. Ruttenberg further stated that wage indices could not become the sole determining factor in deciding how to distribute the proceeds of industry between management and labor. Any inflexible tying of wages to an index would nullify organized labor's approach to get for its members more of the fruits of industrial production.

Mr. Ruttenberg also made the point that advancing technology, in substituting electric power for human power and in substituting "button pushing" for mental and manual skills, results in making the usual job-evaluation factors (skill, responsibility, etc.) inadequate for expressing the basis of wage payment. Under strict interpretation of some present job-evaluation plans, in a case such as the replacement of the old hand-controlled strip mill by the continuous-strip-mill process, the pay per ton of steel produced would be less for the employees, so that at best, the wages of employees would be frozen, whereas organized labor believes that job evaluation should give cognizance to whatever additional factors may be

[4] Director of Research, Steel Workers Organizing Committee, CIO.

required to give to labor an equitable share of the fruits of technological change.

COLLECTION OF WAGE DATA

Robert Myers[5] stated that the Department of Labor has for some time been experimenting with the collection of information on wages by occupations involved. He pointed out that the source material for this information is the employer and that the information should be representative of large and small employers. He emphasized also the complications of collecting information where the various methods of incentive pay are in use. He emphasized that the volume of data is very considerable and that the problem of collecting it would be correspondingly difficult. He concluded that the Bureau of Labor Statistics aims to be of maximum service to its consuming public, and that the extent to which it undertakes collection of such data will necessarily be related to the demand for such information.

E. S. Horning[6] listed some of the present mechanisms for collecting wage data and discussed the extent to which the National Industrial Conference Board carries out this activity. He also discussed the various wage surveys conducted by individual companies or by trade associations in various localities.

He pointed out that a service organization such as the National Industrial Conference Board enters a problem of this sort largely based upon the extent to which there is a public demand for the information. He outlined some of the problems involved in getting promptly information which would result in having wage data for like occupations, and having in addition data on related questions, such as incentive pay, benefits not contained in the pay envelope, and the like.

HOW CONCILIATION SERVICE VIEWS IT

Walter C. Taylor[7] gave a prepared discussion which included the following statements:

As representatives of management, most of you probably consider in connection with wages not less than five items, namely: What is the relation of wage cost to material cost? What wages are paid for similar work in similar areas? What is the relation between the wage proposed and the cost of living? What is the value of a worker in relation to wages in your plant and under what conditions does he work? The most important of these, and perhaps the one that you consider first is: What are my wage costs going to be?

Before making any definite commitment on "index of wage rates as a factual basis for wage determination," I would like to make a few suppositions. If both labor and management were agreed that a highly detailed wage index, broken down as to area, industry, and the specific job, would be acceptable to them, and if statisticians agreed that such an index were feasible, then, as a representative of the Conciliation Service, and only then, would I say that such an index would be of value to a commissioner of conciliation.

The gentlemen discussing the matter this evening have brought to light many interesting points. The aim of our service is to promote harmonious management-labor relations. In all instances our commissioners seek to bring to light all facts that can aid them in bringing about a settlement satisfactory to both parties. Therefore, if a detailed wage index were available, commissioners of conciliation undoubtedly would refer to it as an aid in certain controversies. We, however, would caution continuously our commissioners on the following point regarding wage indices: Watch your step.

An average wage rate is only one of a number of things to be considered. I have mentioned the ability of the company to pay, value of the job, cost of living, and working conditions, but there may be discrepancies in an index, and I ask this question, "Just how descriptive or how detailed is the index you propose?"

There appears to be no direct relation between wage standards and industrial performance in the different areas or industries of the United States. A highly skilled man in one industry may receive less than a less skilled man in another industry. Then it would seem that an index, rather than being a correct one, might be either a low or a high one. And at this point may I inject this thought, output is a very important factor in establishing wages.

Further, it must be remembered that an index figure will change constantly. Every time one company within the index changes its wage rates, naturally the index would change. Another company which has been paying the standard rate of the index might then find it is below the index, even though it had just concluded wage adjustments. What would be the result—a rapid spiral either upward or downward, and such a spiral could not help, but possibly bring about labor and management problems.

Now what is the answer? An actual job-evaluation study should be made before the wage rates paid on a particular job are used as a wage index. Following an evaluation study, many companies change the basic rates of some positions.

If parts of an index are incorrect, then the index definitely could not be an actual wage barometer. An index, other than a general one, would have to be very detailed.

Possibly it appears that I have indicated that commissioners of conciliation should beware of wage indices. We do not mean that the service believes that such indices would be without value. We use the material which is prepared by our Bureau of Labor Statistics advantageously whenever possible. For many years we have been making work-load and wage studies.

The Bureau of Labor Statistics is responsible for wage information. However, the Secretary of Labor has designated work-load problems to the Conciliation Service and during the past years we have worked very closely, when requested by labor and management, on some of their work loads, job analyses, and job-evaluation problems. The purpose of this work has been to determine the work load for particular jobs in an industry, in a chosen area, and to assist the parties in reaching an agreement on the questions of work load and wages.

We enter such problems only when requested by labor and management. We proceed only after a company and union have decided upon the occupations involved and the companies from which data are to be secured. All details are confidential and our information is presented to both parties without recommendation. As a result, in most instances the company and the union have been able to work out a satisfactory solution when these facts have been presented.

Our technical commissioners do not take the place of industrial engineers; it is only a supplementary service. There is no charge for our work. From our experience we find that discrepancies between wage rates within a company without any apparent reason often cause labor-management controversies. The nearest approach to a proper technique to adjust such problems is that of job evaluation.

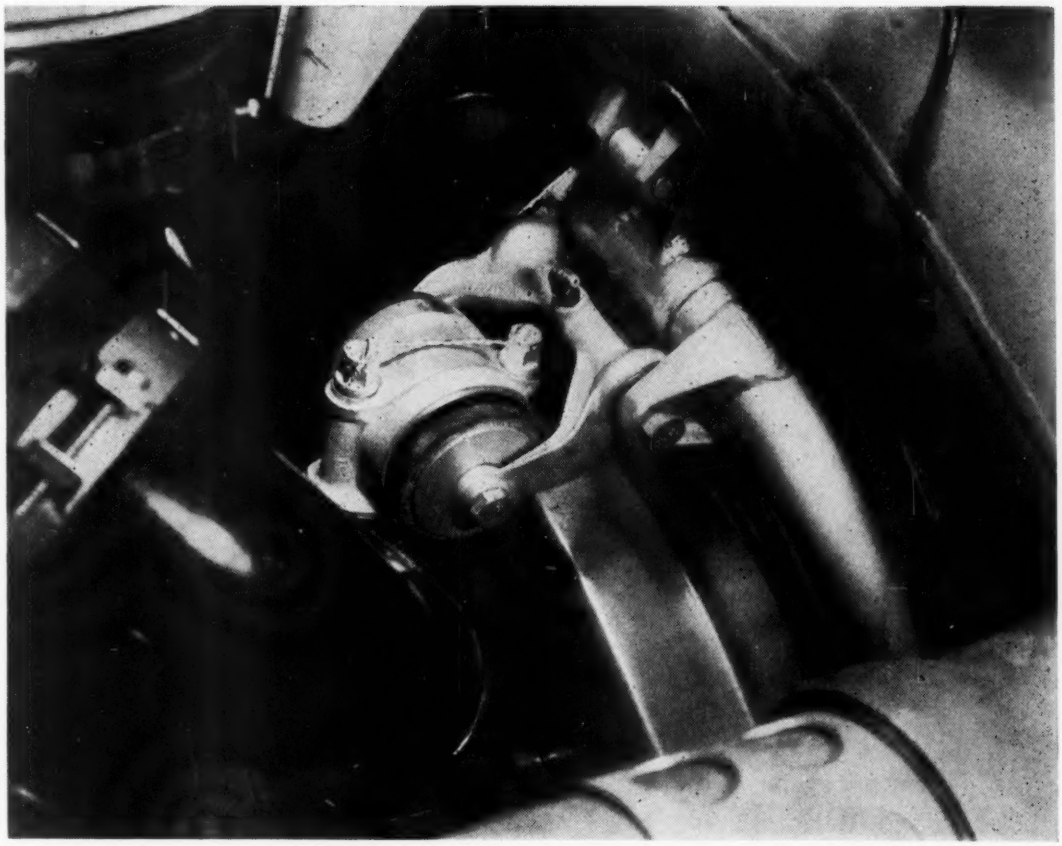
Frequently when there is a dispute, a technical commissioner of the Service is invited in by the union and the company to assist in evaluating the jobs in dispute, or to assist in evaluating all jobs in the plant. We further find that it is very helpful

(*Continued on page 306*)

[5] Bureau of Labor Statistics, Washington, D. C.

[6] Information Research Division, National Industrial Conference Board.

[7] Technical Adviser, U. S. Conciliation Service, Department of Labor.



LINK-TYPE MOUNTING FOR DYNAFOCAL SUSPENSION FOR RADIAL AIRCRAFT ENGINES

ADVANCES *in* RUBBER *and* PLASTICS DURING 1941[1]

THIS is the second annual report (1)[2] to the Rubber and Plastics Subdivision, of the Process Industries Division of The American Society of Mechanical Engineers, on progress during a calendar year in the mechanical technology of rubber and plastics. In a very real sense it is a résumé of many contributions made by mechanical engineers and the technologists of the rubber and plastics industries to the security of freedom. Our effort now must be for defense, but the longer view, which cannot be forgotten, is that developments under the stress of these times will carry over into peacetime benefits.

When the year 1941 was young, the antiaxis powers faced incredibly efficient mechanized forces with commendable courage and appalling deficiencies of matériel and manufacturing capacity. As the year closes, the balance is swiftly changing. This country is on the verge of unparalleled production of the implements of war. Entwined in this great program and essential to it is the increasing influence of both rubber and plastics. New concepts of production, design, weight, assembly, and style are developing, and engineers who keep abreast of the tide can best anticipate future technical needs and price competition.

Although, for commercial reasons, the products of today must in general wait for open technical description until tomorrow, every application indicates a trend, and every trend is based upon substantial technical progress illustrated by the applications. Hence the available literature has significance beyond the details it contains, and suppliers and designers alike can well afford to study it and cannot afford not to if they intend to keep abreast of the swift-moving tide of modern design.

[1] Contributed by the Rubber and Plastics Subdivision of the Process Industries Division and presented at the Annual Meeting, Dec. 1–5, 1941, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Section on Rubber contributed by Felix L. Yerzley.[3] Section on Plastics by Gordon M. Kline.[4]

[2] Numbers in parentheses refer to Bibliography at end of paper.

[3] Engineering Department, Pioneer Instrument Division, Bendix Aviation Corp., Bendix, N. J.

[4] Chief, Organic Plastics Section, National Bureau of Standards, Washington, D. C.

Acknowledgment is made of the suggestions and co-operation of E. Guth, department of physics, University of Notre Dame; G. H. Kaemmerling, Lord Manufacturing Company; F. J. Myers, Resinous Products & Chemicals Company; T. H. Peirce, H. A. King Company; E. F. Riesing, Firestone Tire and Rubber Company; and F. C. Thorn, Garlock Packing Company.

I ADVANCES IN RUBBER[5]

FOR lack of any more generally acceptable terminology the word rubber is used in this report in its broadest sense, and distinction is made between natural and synthetic rubber only when it is particularly important to do so. To a designer, the source is immaterial, the performance paramount, and all generalizations must be qualified without exception by the assumption that each competent designer will know the characteristics required for the performance of a given part and that he will label his requirements by full specifications to prevent installation of inadequate materials. At the same time, the designer must know that when two parts can be made satisfactorily of the same composition, there is much to be gained in uniformity and economy by using the same material specification for both.

The diversity of products required by the armed forces is suggested by the following partial list of products being made by one of the large rubber companies:

Tank track blocks and bushings
Half tracks
Hatch gaskets
Motor mountings
Bogie tires
Self-sealing tubes
Self-sealing gas tanks
Self-sealing fuel and oil hose
Latex-sponge parachute pads
Latex wing fillers
Latex pilot-seat pads
Rubber cement
Various gas-mask parts consisting of

- (*a*) Flat face blanks
- (*b*) Fully molded face blanks
- (*c*) Outlet valves
- (*d*) Deflectors
- (*e*) Hose tubes
- (*f*) Various gaskets

Friction tape
Rubber tape
Radiator hose
Barrage balloons

Further expansion of this theme is found in the literature (2, 3). There is little technical information in published literature specifically related to defense items. There are extremely important developments under way, however, on motor supports, particularly for aircraft power plants. We are indebted to a private source for the following information.

Perhaps of primary importance in the aircraft-engine-mounting field has been the standardization and adoption of Dynafocal Suspension for the mounting of large radial engines. Dynafocal Suspension is the trade name applied to a directional spring-mounting system so arranged as to obtain a virtual center-of-gravity suspension, even though the mountings are necessarily attached to the rear of the engine. By its use isolation for all types of vibratory disturbances arising from the engine-propeller combination can be achieved without the introduction of an undue amount of instability such as usually would occur with an overhung suspension made adequately soft to give the desired isolation.

In these suspensions the use of shear-stressed rubber as the flexing medium has been employed as being the most efficient and easily applied method of achieving the flexibility. Designs are of two types, the link type and the flexible pedestal or inclined-sandwich type. In the link type Dynafocal Suspension, bonded-rubber tube-form mountings are arranged tangentially to a circle, the center of which is the crankshaft center line, and connection is made to the structure by means of links which are inclined toward a focal point slightly ahead of the center of gravity.

In the pedestal type, bonded-rubber sandwich-type mountings are used, with the sandwiches inclined so that focal lines drawn normal to the plane of the sandwich would again meet at a point slightly in advance of the center of gravity of the supported assembly.

The use of rubber mountings in aircraft for shock and vibration control has become standard procedure. The most common applications are on instrument panels, radio, individual instruments, and cowls. Both radial and in-line engines are usually mounted on rubber mountings.

Extensive additions have been made to the variety of commercial mountings, and it is fair to assume that the number will continue to increase. The following data on mountings for compressive loads appeared recently (4):

	Mounting load, lb	Minimum disturbing frequency, cycles per min
A	250	850
B	150	1200
C	85-100	1250

The impelling motive behind most applications of rubber springs for mounting purposes in all classes of machinery is the reduction of vibration. An important analysis of vibration in automobiles (5) was presented. Intensive work is being conducted in laboratories throughout the country on mounts for all types of internal-combustion engines in marine, railway, automotive, and aviation equipment. Further refinements and novel improvements can be expected.

The automotive industry has continued to lead in the application of rubber. Wide-rim pneumatic tires have been introduced (6) for which greater riding comfort and road stability are claimed. A variety of rubber and synthetic-rubber parts have been added to automobiles and have been described in excellent papers (7, 8, 9).

During the year semiconducting rubber has come into large-scale commercial production. It is made by the inclusion of specific types of carbon black in the compound. Application is found in quantity where static electricity must be dissipated. Industrially, the explosives, petroleum, and transportation industries afford the biggest markets for belting, footwear, and tires. Static elimination in the operation of automobiles prevents the danger of shock and improves radio performance (10, 11, 12). Semiconducting rubber is also applicable for heating purposes and is used in this manner in flying suits for use at high altitudes.

Compression and stress decay in rubber gaskets often are serious questions in design. An analysis of experimental results led to the following recommendations for longest useful life (13):

1 Roughened flanges and absence of lubricating paste.
2 High initial load short of the crushing strength of the material.
3 Thin gaskets.

Vibration isolation has continued to pose the question regarding the possibility of making rational analysis related to practical application of the damping (hysteresis) properties of rubber. Reports expressed from several sources indicate that ideal spring systems can be obtained by the proper combination of metallic- and rubber-spring components. Large harmonic

[5] Section on rubber prepared by Felix L. Yerzley.

CUTAWAY SAMPLE OF SANDWICH-TYPE MOUNTING FOR DYNAFOCAL SUSPENSION FOR RADIAL AIRCRAFT ENGINES

balancers of the torsional type are being installed in production on the crankshafts of marine Diesel engines.

Further tests have been reported bringing out additional information on the mechanical characteristics of rubber. One interesting paper deals with a variety of spring shapes and the relative importance of shear, tension, and compression in the over-all spring rate (14). Static fatigue life was studied comprehensively by other investigators, and important information on permissible stresses and strains is indicated (15). An especially valuable paper (16) on the creep of natural and synthetic rubbers over periods as great as 900 days was presented before this subdivision, probably to become the cornerstone of extensive literature on this subject. A paper on the creep of neoprene provides supplementary information (17). Several synthetic rubbers are compared in various ways in a timely paper presented to automotive engineers (18).

While product engineers have been given the spotlight, process engineers have been active on important factory problems. One engineer visualizes rapid transition of the rubber industry from batch processing to continuous processing (19). Another engineer called attention to the ever-important problem of safety on mills and calenders (20). Progress in the theory of elasticity was also reported (21).

Maintenance of raw-material supply was especially interesting in connection with synthetic rubber. The question was dealt with in lucid and important papers (22, 23). Production estimates for all types are well over 22 million pounds for the year with predictions for 1942 far in excess of this amount. This estimate includes both oil-resistant and other types.

The synthetic-rubber picture is made more interesting by the continuance and acceleration of research. During the year gradual development of all types has made them more useful and more readily processed. In addition, major contributions to rubber technology have been marked by two entirely new types of neoprene, one of which can be plasticized to putty-like consistency before vulcanization, the other an oil-resistant material having freeze resistance comparable with that of rubber.

It is impossible to predict the nature of things to come, but it is definite that the assimilation of new knowledge and new materials will be reflected with increasing brilliance in the literature and products of 1942.

II ADVANCES IN PLASTICS[6]

THE keynote of the year in the plastics industry was, of course, the defense program with its attendant opportunities for expansion into new industrial applications and its disruption of many of the normal markets for plastics. Despite the general difficulty experienced in obtaining all the supplies of molding powders desired, preliminary estimates indicate that the volume of plastic materials produced during 1941

[6] Section on plastics by G. M. Kline.

was about fifty per cent greater than in the preceding year. However, even this record-breaking production was not sufficient to permit realization of a goal set early in the year to relieve shortages in metals needed for defense by replacements with plastics; and the rapid development of demands for plastic parts to be used on military equipment quickly led to the establishment of preference ratings for deliveries of certain types of synthetic resins. As the end of the year approached, all plastics were under surveillance with an allocation program for practically all types in the offing.

The expanding outlets for plastics in defense were highlighted in the 1941 *Modern Plastics* competition awards (24). Airplane manufacturers used molded, laminated, and fabricated plastics for outstanding developments in gun turrets, nose sections, cabin ventilators, aileron control quadrants, radio antenna masts, cabin paneling and flooring, and fluorescent instrument panels. A black-out glare-free lighting unit having cellulose-acetate louvers facilitates inspection work in defense factories. Extensive use of plastics in a radiosonde, which transmits records of pressure, temperature, and humidity in the upper atmosphere, permits the more efficient attainment of data needed for long-range weather predictions required in military and aeronautical work. Successful applications of plastics to even more direct and important items connected with defense were achieved late in the year and others are progressing satisfactorily through the experimental stages.

MATERIALS

There were no outstanding developments in new plastics during the year 1941, inasmuch as all efforts were concentrated on increasing the output of established products. However, toward the end of the year considerable attention was devoted to the possibilities of using certain natural products to extend the available supplies of molding powders. Of primary interest in this connection were furfural, lignin, soybean meal, and bagasse. Producers and molders alike are accumulating a background of experience in processing these materials and a stage has been reached at which the selection of particular formulations for concentrated commercial development is feasible.

Numerous articles were published regarding further developments in plastic materials and fillers. The use of urea resins as adhesives expanded (25) and melamine resins were employed in molding compositions as well as to a greater extent in protective coatings (26). Cast phenolics, in accord with the trend of the times, took on industrial jobs such as forming tools in aircraft factories and parts for oil-well-drilling operations (27). Many improvements were reported in reinforcing agents for use with phenolic resins, most of which were significantly directed toward increasing the toughness and impact resistance of the plastics to make them more suitable for rugged work. These developments related to the use of creped paper (28), wood pulp (29), glass fabrics and filaments (30), sisal (31), cottonseed hulls (32, 33), metal powder (34), and mica (35) in plastic compositions. Resin-treated and compressed wood suitable for molding and fabricating into metal-forming dies and airplane propellers was described (36). Further progress in the preparation of plastics from lignin (37, 38, 39, 40) and soybean protein (41, 42) was reported. Several surveys appeared on materials about which little had been previously published: vinyl alcohol (43), starch (44), zein (45), and coffee (46) plastics. It can be assumed, however, that many new developments in synthetic resins were kept in the laboratory because of lack of plant facilities and personnel to undertake their commercial production.

MOLDING AND FABRICATING

Continuous extrusion made phenomenal strides during 1941 and is providing plastics in decorative and structural shapes to replace aluminum, stainless steel, and other metals reserved for strictly defense purposes. The process differs from the former technique employed in making rods and tubes in that the composition hardens simply by cooling; whereas previously, solvent had to be added to obtain proper flow and this solvent had to be removed in a seasoning process. Fairly intricate shapes can now be made on a commercial basis from the various thermoplastics, including vinyl resins, polystyrene, and the cellulose compounds. This process is being extended to larger and more complicated shapes as improvements in materials, machines, and dies are effected (47). Special awards were given in the 1941 *Modern Plastics* competition for developments in extruded plastics for use as furniture and cabinet trim, interior decoration, window trim, upholstery for transportation and theater seats, and colorful fabrics of unusual strength and resiliency.

Fabrication of aircraft structures by the rubber-bag molding process was the subject of several papers during 1941. Its successful operation in a number of plants in this country has demonstrated that it is a practicable method for producing airplanes; moreover it uses materials and labor which are more readily available than those required for metal aircraft (48, 49, 50, 51, 52, 53).

APPLICATIONS

The aircraft industry continued to explore and utilize plastics in new ways during 1941. In addition to the items which received special awards as previously mentioned, other achievements in the fabrication of aircraft parts from plastics were reviewed by various authors (54, 55, 56, 57, 58, 59, 60, 61). The use of resin-impregnated compressed wood for the mass production of propellers was of especial interest (62, 63) in view of the reports received from England of their continuing successful operation.

Resin-bonded plywood provided the answer to many problems arising in connection with shortages of materials in the defense program. It has been used extensively in defense housing and small-boat construction (64, 65, 66, 67) and, as the pinch in steel becomes more acute, it is probable that this weather-resistant structural material will get further recognition in the defense industries.

There was considerable activity during the year in the molding of plastic lenses, particularly for gas masks and safety goggles and spectacles (68, 69). Three patents relating to molding and polishing plastic lenses (70, 71, 72) were issued to one optical firm. A plastic contact lens for use directly against the eye is also on the market (73, 74, 75).

Synthetic resins became available in this country during 1941 for use in water softening and purification, recovery of valuable substances from solution, removal of dissolved salts from biological and pharmaceutical preparations, and other special applications involving separation of dissolved constituents from solutions. This function of synthetic resins as ion exchangers focuses attention upon their chemical properties in contrast to previous emphasis on strength, hardness, inertness, and color. An extensive research involving the preparation of many different types of synthetic resins and the development of a rapid method for evaluating their efficiency as exchange adsorbents preceded the selection of the particular ion-exchange resins now in commercial production (76, 77, 78).

Advances in the application of plastics in many industries were summarized in reports covering fluorescent lighting (79), refrigerators (80), wire covering (81), phonograph records (82), dentures (83), wearing apparel (84, 85), automobiles (86, 87, 88, 89), grinding wheels (90), electroplating (91), chemical filters (92), and chemical-plant equipment (93, 94).

TESTING AND PROPERTIES

Measurement of the flow of thermosetting and thermoplastic compounds at molding temperatures was the subject of seven papers published during the last twelve months (95, 96, 97, 98, 99, 100, 101). These investigations included work with the flow tester used in the tentative standard methods of the American Society for Testing Materials as well as with several new devices developed for special purposes.

The flammability of plastics was studied by two groups of investigators. The results of round-robin tests performed by A.S.T.M. Committee D-20 on Plastics in developing its tentative standard method were described in one paper (102). Comparative burning rates of various plastics were reported by the Underwriters' Laboratories in another publication (103). Plastics, other than the pyroxylin type, were divided into three classes according to the latter bulletin, corresponding to non-flammable, self-extinguishing or difficultly flammable, and slow-burning materials.

The dimensional changes which plastics undergo when subjected continuously to boiling water for long periods were tabulated in an important contribution from the Mellon Institute (104). This paper provided additional information regarding the dimensional stability of plastics when immersed in water to supplement that published late in 1940 by the National Bureau of Standards (105).

A simple device for determining the flexural strength of plastics was described by the Regional Soybean Laboratory (106).

Five papers pertaining to plastics were presented at the 1941 annual meeting of the American Society for Testing Materials. One of these related to a chemical method for detecting free phenol in bottle closures which gave a satisfactory correlation with taste tests involving these closures (107). Another pertained to tests made at the University of Illinois on the mechanical properties of cellulose-acetate plastics, including tensile strength, elongation, tensile endurance limit, and flexural fatigue properties (108). Shear strength, creep, and cold flow of various types of plastics were reported in two papers from the Plastics Industries Technical Institute (109, 110). The resistance of plastics to immersion for a 7-day period in representative types of chemicals was the subject of a report from the National Bureau of Standards (111). The effects of the chemicals on weight and dimensional changes and appearance or condition of the plastics were tabulated.

Six new tentative methods of tests for plastics, a procedure for preconditioning plastics for testing, and four revisions of existing tentative test methods for plastics were adopted by the American Society for Testing Materials (112). The properties covered by these methods were color fastness, light diffusion, deformation under load, flammability, flow temperature, impact resistance, resistance to chemicals, optical uniformity of flat transparent sheets, and tensile strength.

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BETTER UTILIZATION *of* COAL

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PROGRESS toward better utilization of coal has been brought about through the joint co-operation of the user, the equipment manufacturer, the coal producer, many chemical and engineering laboratories, and the United States Bureau of Mines. The consumer of coal has perhaps played the most important part, because in buying coal and the equipment in which it is burned or used, he has had the choice of continuing with that which was in vogue at the time or of being progressive and trying out new or improved equipment for his requirements. Many equipment manufacturers have been on the alert to improve their products, and thereby to enable a user to improve the efficiency, increase the capacity, and perhaps take advantage of a lower-priced fuel. The many educational and technical laboratories and the Bureau of Mines have extended the knowledge of fuel by better methods of sampling and analysis, and have made available determinations regarding the calorific value, fusing temperature of ash, grindability of coals, and agglutinating properties, all of which have had their beneficial part in the progress. The coal producer has been co-operative and helpful in preparing the coal as to size and quality to meet the requirements of the user and the equipment available.

CONTRIBUTIONS BY USERS

Iron and Steel Industry. One never thinks of iron and steel without thinking of coal, coke, and other fuels. The steel industry consumes something over 20 per cent of the bituminous coal in original form and as coke. It has persistently improved the use of coal by economies in methods of combustion, preheating air, and in every way possible, so that in the period of the last 25 years it has decreased its fuel consumption per ton of output by something over 22 per cent.

Closely associated with the steel industry is that of coke-making. Nearly 40 years ago, when the author first became directly connected with the coal industry, he was surprised to find that more than 90 per cent of the coke was made in the dirty, wasteful, beehive oven, when there were in operation at that time four or five sets of by-product ovens which were obviously superior in every economic way. However, it was not until 1916 that any great headway was made with the by-product oven, and only 10 years ago that coke production swung over to more than 90 per cent of by-product.

The gas industry also deserves some credit for promoting the extension of by-product ovens for city gas and domestic and foundry coke. During the last 25 years, the recovery of gas, tar, oil, and breeze, expressed in equivalent coal value, has been increased by 400 per cent. On a basis of 70 per cent coke recovery, this is equivalent to about a 25 per cent increase in the coal value of fuels resulting from by-product operation over the beehive and the smaller percentage of by-products which existed 25 years ago.

The iron and steel industry has also made better use of blast-furnace gas, coke-oven gas, and all kinds of fuels which result directly and indirectly from the use of coal.

Railroads. The railroads are also very closely associated with the coal industry, both in its transportation and consumption. The railroads burn approximately 20 per cent of the total coal production, and they, too, have been active in furthering its more economical use to the extent of reducing their coal per 1000 ton-miles by about 34 per cent during the last 25 years. This reduction is the more remarkable because it has been brought about not by changing any major feature of locomotive design, but by many increments. Most of it has been accomplished not in the combustion of coal itself, but rather in the more efficient use of steam through superheat and higher pressures, better care of the engines, and also by a great deal more attention being given to the rolling stock, handling of trains, etc. The actual firing has been improved markedly by greater care being given to methods of firing and by the extensive adoption of stokers. The locomotive still rates as a very inefficient fuel-burning equipment, because of very high rates per square foot of grate surface and heating surface, so that its carbon and cinder losses and high gas temperatures are necessary evils which accompany the heavy duty required of a limited size and weight of equipment permissible.

Cement Industry. In 1940, the cement industry used 5,600,000 short tons of coal, which is slightly over 1 per cent of the total bituminous and anthracite production for the year; yet in the author's opinion it deserves recognition as third place in so far as its contribution toward better utilization of coal is concerned. This is because some 43 years ago the cement industry started to use pulverized coal in rotary kilns, and, in spite of certain difficulties, it members persisted in carrying it through to a satisfactory economical attainment which has not yet been paralleled in any other industry.

At about the same time the cement industry started using pulverized coal, it was attempted in steel plants, under steam boilers in power plants, and in other applications, where the first efforts were chalked up as failures and abandoned experiments. Whether it was because the cement industry was in the business of pulverizing material before burning it to clinker, and again into the final finished cement, that they went the whole way and completely pulverized all of their fuel successfully, or whether it was because they were more persistently intelligent than others, cannot be stated. It is true that the ash problem, as it appears in boiler and many metallurgical furnaces, did not have to be solved in the cement kiln. However, the record speaks for itself and, now that the use of pulverized coal has been so successfully extended into many other types of equipment, the cement industry must be recognized with gratitude for its great contribution in this program of progress. In no place more than in the Lehigh Valley has this history been written.

Electric Utilities. While the electric utilities consume only about 12 per cent of the total coal production, they rank very high in the classification of better utilization of coal. While this industry started only 59 years ago, its most active life has been during the last 40 years. During the last 20 years, when reliable records have been available, its fuel consumption per kilowatthour has been improved about 60 per cent on the average, and the better modern plants deserve a credit of 75 per cent improvement in the fuel per kilowatthour. This result has been possible because of its rapid growth, as the industry was adding to its equipment at relatively frequent intervals. The cost of fuel was a high percentage of its cost of production. It at-

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tracts the best engineers in the country, and they have been free from competition with each other to such an extent that they have co-operated extensively in exchanging ideas and information, with the result that, with very few exceptions, each new installation has been a definite improvement over that which preceded it.

Again, these results have not all been accomplished in the burning of coal itself. By going to higher steam pressures, higher steam temperatures, and extensive feedwater heating by stage bleeding, improved turbine design, air preheating, and better equipment throughout the entire station, these results have been accomplished. Nearly one half of this has been brought about in the better efficiency of the fuel-burning equipment, and in the boiler itself, as a heat-absorbing unit. All this has been accomplished in spite of the fact that the higher steam pressures and higher steam temperatures have of themselves contributed adversely toward improved heat-absorption efficiency.

Not only have the utilities accomplished these results for themselves, but they have been an open book to all industrial steam engineers who have visited their stations, observed their results, and copied them as much as they felt inclined to do.

Manufacturing Industries. This classification covers a wide variety of industries which use coal and fuel for power generation, steam, and direct heat in processes. Collectively they rank as the largest coal user, consuming about 25 per cent of the total production. There is naturally no specific basis of comparison by which their improved efficiency can be measured. In burning fuel for the generation of steam, some are on a par with the better central-station plants, while others are very backward and are still burning coal very inefficiently in antiquated equipment. Some of the more progressive companies have put in units of higher pressure than the average electric utility, largely because the heat required in their process has not changed as fast in their increased production as has their kilowatt requirements for power in pumping and handling materials, etc., at the higher production rate. This, therefore, leads economically to the installation of high-pressure boilers and turbines, exhausting at suitable pressures for process steam throughout the plant.

Marine. Marine engineering has contributed a net loss to the coal industry. It is mentioned here in connection with the two preceding industries, as its fuel is used for the production of steam under circumstances somewhat similar to those prevailing in locomotive and stationary plants, but the economic requirements are quite different.

Ocean-going tonnage has changed almost exclusively to oil as a fuel. When the price of fuel oil came close enough to the price of bunkering coal, the change was inevitable because of the greater facility in bunkering, storage of fuel, handling it aboard ship, reduction in labor, etc. Only a few of the ocean-going vessels of American tonnage have retained coal. Those isolated cases were where a company transporting its own coal felt justified in using coal as a fuel rather than oil. Many of the smaller harbor craft around New York and other Atlantic seaports are still burning anthracite or other fuels in equipment of many years' service. The majority of the Ohio and Mississippi river craft are still coal-burning, but oil-burning boilers and even Diesels have gained headway, even to the extent of hauling coal with boats burning oil fuels.

On the Great Lakes oil has come into extended use on passenger boats for greater cleanliness and convenience, but on the cargo boats coal still reigns supreme. Many of the boats are still hand-fired and doing discredit to the sky line, but rebuilt and new vessels are installing stokers and modern equipment, such as has been developed in stationary plants. There is a great deal to be said in behalf of the seemingly backward progress of marine engineering on the Lakes when the relatively small power in each boat and the seasonal schedules necessarily followed are considered.

Retail Domestic Heating. While this market ranks high in coal consumption, being about 20 per cent of the total, it rates last in so far as progress in better coal utilization is concerned.

Naturally, house heating has responded less quickly and effectively to improved coal-burning equipment. The reason is largely because it is the most difficult problem to solve to the satisfaction of those interested, namely, the stove and furnace manufacturers, the house owner or tenant, and the coal dealer and the coal producer.

In recent years, the coal producers, driven largely by competition from gas, oil, and other fuels, have taken up the problem of developing better coal-burning equipment for the home. It is rather necessary for them to do this, because it is a very large tonnage spread so thinly over so many millions of users that the users themselves cannot contribute anything toward developmental work, such as has been done so well by the users of larger tonnage in the electric utilities, railroads, and steel industry. There has been a very active development of house stokers, and here again the equipment manufacturer deserves a great deal of credit toward the development in coal utilization.

Petroleum. While the petroleum industry burns a small tonnage of coal now and then in its refineries, when it suits economic convenience to do so, it is brought into the picture here more as an explanation of the great spur which the coal industry has received from outside competition actually to reduce its consumption by better efficiency in its utilization.

PROPERTIES OF COAL

Perhaps, before going on to the specific developments in the way of equipment which have contributed most toward better utilization of coal, it might be well to state the problem.

Even anthracite, although an ideal fuel in many ways, is not without its faults in using it conveniently and efficiently for every purpose. It is somewhat difficult to ignite, and sometimes it goes out when most inconvenient. It has ash, which must be removed from the stove or furnace and disposed of. While anthracite has lost part of its market to other fuels of greater convenience, its cost at more distant points from the anthracite region has also contributed toward this end. Developments in house stokers, grates and furnaces for power plants, and the adaptation of pulverized anthracite to the larger units have contributed much toward its survival and, under the present economic conditions, to its increase in production.

Bituminous coal is easier to ignite and burn than anthracite, but as its name implies, it has bitumen, or volatile as we usually call it, which creates a very difficult problem in its burning, by many of the methods used in the past. The problem of burning bituminous coal cannot be appreciated fully until it has been handled in the raw in beehive coke ovens, and the slow distillation process observed as it occurred, beclouding the whole countryside with a continuous cloud of smoke and dirt. This fortunately has been remedied through the use of by-product ovens. Today the demand for coke exceeds the capacity of these ovens and some beehive ovens have been restored to service.

The next place where bituminous coal is fired under conditions which arouse indignation and ambition is on flat grates in a hand-fired furnace, either in stationary, marine, or locomotive service, where the effort is to keep a good, efficient fire, with a minimum of backbreaking labor. The coal melts into a black, gooey, obstinate mass through which no air can be forced until it has run its course of stewing off the volatile and getting down to a coke, which perhaps has to be broken up and leveled to fill

the holes before arriving at some semblance of a good-looking fire. After only a short period of this clean fire, it must be messed up again by adding fresh coal and the process is repeated, in the meantime inflicting the countryside with a trail of black sooty smoke. All the time, ash is accumulating, which may fuse into a hard vitreous clinker on the grates. At intervals this must be removed with slice bar and hoe, and the operation repeated ad infinitum. While to some this may all seem like dark ancient history, it has taken such firsthand experience to drive manufacturers and inventors toward improvements in stokers and other coal-burning equipment, resulting in improvements which are more widespread today; yet there are too many smaller plants still being operated in this reprehensible manner.

Again, those of us who were raised in localities where house heating and cooking were done with bituminous coal, in Franklin stoves and other primitive equipment, have watched the geysers of white flame shoot from the tarry mass, and stew along hour after hour with the smoke going up the chimney just the same. There were coal scuttles to fill, fires to bank, and ashes to clean out and remove.

Returning to the properties of coal in comparison with other fuels: First, it is a solid; it will not flow. It has to be carried or handled and transported in a less convenient manner than being forced through pipes, as in the case of gas and oil. Its volatile matter, its agglutinating and coking properties, its smoke-producing properties have all been described more forcefully than they can be by reading chemical analyses. It contains ash, which is the least of its troubles in the firing process in the small hand-fired furnaces just described. However, as it is burned in even the most improved types of stokers, in the form of pulverized coal, and what not, the ash is still with us and opens up problems which of themselves are requiring and receiving the attention of many engineers, in an effort to minimize the difficulties resulting therefrom.

EQUIPMENT FOR BETTER UTILIZATION OF COAL

By-Product Coke Ovens. As already mentioned, the by-product oven has contributed perhaps more than any other one type of equipment toward better utilization of coal for a very important purpose. The tonnage of coal so processed exceeded 75,000,000 tons in 1940.

Stokers. The first important step made in an endeavor to burn coal more efficiently or conveniently and at higher rates of combustion is the mechanical stoker. The principal basic types are the traveling or chain-grate stoker, the overfeed, underfeed, and spreader-type stokers. Each type has its respective merits for different conditions, or for use with different kinds of coal, with perhaps the underfeed and the spreader-type stoker predominating today over the overfeed and the chain-grate. Stokers have their most extended use today in power boilers, industrial furnaces, locomotives, and to a greatly increasing extent, in domestic equipment. Statistics covering equipment purchased by the electric utilities definitely indicate that, in the larger sizes prevailing in such plants, the stoker is losing out in relation to other methods of burning coal.

Pulverized Coal. Pulverized coal is being successfully burned in the bin-and-feeder system which prevailed in the early days of its existence in cement plants, as well as in power stations. However, today direct firing is gaining rapid headway in replacing the bin-and-feeder system, even in the cement industry. In central stations, and in all but the smaller industrial plants, pulverized coal is gaining in use. It is still the relatively newer way of burning coal, especially in water-cooled furnaces. Pulverized-coal burners are far from being perfected. Great improvements are continually being made in better methods of feeding and burning the coal in the furnace.

Regardless of where coal is burned, the ash is still present, and must be contended with. When coal is burned in cement kilns and in similar metallurgical furnaces dealing with a large quantity of products, the ash causes no difficulty, as it either combines with the product or passes off with the dust from such furnaces and is beyond distinction from other dust. In boiler furnaces, the ash is more of a problem, because the gases must be cooled in passing through the water-cooled furnace, boiler bank, and superheater. The condition of the ash should be kept within limits where it will not seriously interfere with the rate of heat absorption, and above all will not clog gas passages to the extent of restricting the draft and capacity desired from the unit.

The clogging of gas passages with ash and slag became a serious problem, during the period that the output from steam-generating units was being doubled, and doubled again, over what it used to be. At present it is recognized as one of the basic factors to consider in designing and arranging furnace and heat-absorbing surfaces.

There are two types of ash removal from pulverized-coal-fired furnaces: (1) This is where the ash is removed in the dry state, sometimes being a bit tacky and conglomerating into larger clinkers but is removable by lancing or otherwise without an excessive amount of labor or trouble, and is conveyed or sluiced away in a manner similar to stoker ash after it is removed from the furnace. This calls for a relatively cold furnace and low rates of combustion. (2) This type is the slag-tap furnace where, in the hotter zone or the primary furnace, the ash is hot enough to melt and run out like slag from a blast furnace or cupola, dropping into water, where it breaks up and is conveyed to the point of disposal. Slag-tap furnaces have been designed for continuous tapping, the ash running in a continuous stream into water, where it breaks up and is removed periodically. In other furnaces the ash accumulation is retained in the bottom of the hot furnace and tapped out intermittently, more the way in which the slag is tapped from blast furnaces.

With dry-ash removal, or either type of slag-tap furnace, there is still some ash not collected within the furnace. That which accumulates as sponge ash or dust on the tubes and heating surfaces must be cleaned periodically in order to keep the surface operating efficiently. Some of this ash drops back into the furnace or discharge hopper, and some goes on as dust with the continual stream of fly ash which leaves the furnace proper. In most modern plants it is collected in dust collectors. Slag-tap furnaces collect approximately one half of the ash, so that there is a lesser amount to collect from the stack gases, and in several instances fly ash, so collected, is returned to the slag-tap furnace for remelting and disposal in the most convenient and inoffensive way.

Multiple Fuels. One very important factor which has favored the extension of pulverized coal over stokers is the flexibility of pulverized coal burned in suspension in furnaces where gas or oil may be considered as alternative fuels. During recent years when the oil market became highly competitive with coal on the Atlantic seaboard, many plants having stokers removed them or bricked them over and burned oil. If a change of the market were such that it was advantageous to return to coal, stokers were often either inoperative or became so antiquated that they could not readily be restored to service. The user either continued to burn oil against the true economics, or was faced with a major expenditure for new units or for rebuilding furnaces. In order to meet such situations, many plants during the last several years have installed boilers and furnaces, suitable for either fuel. Sometimes they started with coal, but kept them ready for a change to oil if desired. Many started on oil, with provision to use coal when needed. During the last year or two, coal has replaced oil in many such plants.

Water-Cooled Furnaces. While the old Scotch-marine, Lancaster, and other early boilers were completely water-cooled, as is the locomotive boiler, they were outmoded in an effort to obtain better efficiency and less smoke during a period in which large refractory furnaces were being installed very successfully. Then, as the boilers became larger and the ratings higher, the refractory was unable to withstand serious erosion from ash and slag, so that water cooling was applied, first to the more vulnerable spots, and later to the complete furnace itself on all sides. Even oil-fired furnaces, where trouble from ash was less pronounced, have largely gone to water cooling in the interest of over-all economies and lower maintenance costs. Today much of the fuel oil is getting higher in ash, so that the slag problem is of considerable importance there also, and the remedy again is water cooling.

Meters and Combustion Control. A very appreciable factor in better utilization of coal and other fuels has been brought about by the testing departments maintained in the electric utilities and the larger industrial plants. Even before the days of recording meters and automatic control, such departments checked up on the operation of coal-burning equipment with the aid of gas analysis, temperatures, and draft gages, so that operation was improved, equipment checked, and better efficiencies obtained.

Naturally, as time went on, many of these data were recorded continuously for each boiler unit, so that not only the steam output but the efficiency of combustion was a matter of record, and such records were produced immediately in front of the operator so that he could be guided at all times toward better results. The adaptation of such instruments has been extended so that temperature recorders, draft gages, water-conductivity meters, and other instruments are available in all of the larger modern plants. Some of this equipment is found on practically every boiler operating at 10,000 to 20,000 lb of steam per hour or more.

The next step was logically to have the metering equipment connected to automatic control, so that the desired results could be obtained without continual vigilance and adjustment by the operator himself. Today, steam pressure is maintained, feedwater is controlled, fuel and air are proportioned, superheat temperature continuously adjusted—all automatically, in boiler furnaces, whether using stokers, pulverized coal, or other fuels.

Feedwater Treatment. The best utilization of fuels cannot be discussed without paying tribute to the feedwater chemists, who have so largely eliminated tube losses and the formation of scale from impure water, thereby reducing boiler outages resulting from that source. The deaeration of feedwater is also essential in the higher-pressure jobs to prevent corrosion and wastage of the boiler tubes and pressure parts.

CO-OPERATION

Progress in better utilization of coal would unquestionably have been faster had there been opportunity forty years ago for those who were working in this field to meet as we now are. The author's early experience fortunately was on steamships and locomotives, as well as in small and large stationary boiler plants of that day. Each required the same coal to make the same kind of steam, but how differently they did it. Metallurgical furnaces and cement kilns brought still further variations in ideas and methods working toward the same end.

The cement industry's first successful use of pulverized coal was in the bin-and-feeder system, which was later installed in power-boiler plants. But the direct-fired system has now almost entirely superseded the bin-and-feeder system in boiler plants, and is being actively carried back into the cement industry.

Developments in one field are often carried into others, hence co-operation is profitable to all concerned. This is mostly brought about through the agency of the equipment manufacturer as he crosses the lines often existing between many industries.

We have been slow in developing fuel engineers and giving them the opportunity to interchange information and data. Engineering colleges still do not give this subject the attention that is warranted, in view of the opportunities it presents to young engineers. This applies even to schools which make a special effort to train fuel engineers. Co-operation will be greatly needed because we are still far from our goal of making coal the equal of any fuel in convenience as well as in economy.

FUTURE DEVELOPMENT

It is not always safe to predict the future in too much detail, but the author feels that the following trends are inevitable.

Smaller Sizes of Coal. As stated previously, one of the difficulties with coal is that it is a solid substance and is not a fluid. However, a hasty review of the trend toward mechanical stokers and pulverized-coal burners, as well as by-product coke ovens and the gasification of coal, indicates that coal must approach the fluid state in order to obtain better results from its use and better competition with oil and gas. As this cannot be done completely the next best thing is to reduce coal to a smaller size and put in coal- and ash-handling equipment so that, with a minimum of labor and difficulty, it flows from the cars through crushers, through the furnace and the ash remover, out to disposal. This has been the definite trend. Stokers were first developed to use the slack coal which was screened out of the domestic sizes, and lake coal. Now much coal is carefully sized to meet the needs of certain stokers. Of course all coal to be pulverized need have no special sizing and slack or screenings are generally used. Sufficient progress has now been made for one to see that, ultimately, all coal mined, both bituminous and anthracite, will be crushed to a size approaching a suitable handling condition which will minimize dirt and dust, and actually approach a fluid.

In other words, the coal industry must soon realize that the high prices they have been, and are still, receiving for lump and the larger prepared sizes of egg and nut will ultimately fade away. Such coal is now being sold at the highest prices and is being used most inefficiently in antiquated equipment which will disappear with the advent of improved and smokeless methods of combustion. All coal produced will be shipped or at least used in the smaller sizes, the price for which will be gradually readjusted in the direction of higher and higher prices to bear a just share of the total production costs. This trend should be recognized and frankly faced by both producer and user, and especially by those users who have been paying a disproportionately lower cost for their small-sized fuel for stokers and pulverizers. The coal industry must again guard against further inroads from gas and oil as this inevitable change gradually takes place.

Pulverized Coal. Pulverized coal has made an aggresive inroad into other methods of firing, and the trend will undoubtedly continue in the larger-sized units. Slag-tap furnaces will prevail over dry ash removal, especially as the higher-fusing-ash coals, which have been plying the stoker markets and are more nearly exhausted, will ultimately disappear, and the lower-fusing-ash, higher-sulphur, high-volatile coals will be the long-range coals of the future. For handling such coal, pulverized, slag-tap furnaces are superior. Pulverized coal is not likely to be the universal fuel. It does not seem at all adapted to household use, even though it has been tried repeatedly, nor is it likely to find extensive use in the smaller

steam plants. That, however, is a question of developing certain equipment and the relative prices of coal and oil or gas.

Multiple Fuels. There will undoubtedly be a further tendency toward installing all coal-burning equipment so that it can readily be changed over to oil or gas. This is definitely true on the Atlantic seaboard, for many people believe that, after the present emergency is over, there will be a great supply of very cheap oil available. On the other hand, fewer will install oil-fired equipment that cannot be changed over to coal than have in the past, because they have seen oil largely taken away from them by increased prices and by allocation. Hence, coal must be recognized as the basic fuel to which everyone can and should turn, in cases of necessity at least, even though economics does not always justify it.

Locomotive Applications. In the locomotive field, where less efficiency is now obtained in burning coal than in any other extended use, there will undoubtedly be a trend toward pulverized coal as an offset against the inroads made by the Diesel. The Diesel and other oil-burning locomotives naturally have a place in the West and Southwest, where oil is the more economical fuel, but, when the convenience or the advertising features of the Diesel bring it into the coal regions, then it is time for someone to wake up and meet the challenge. That is going to be done.

There seems to be slight chance for coal to regain its position of 40 to 50 years ago in the tidewater bunkering market. On the Great Lakes and rivers, however, every improvement should be studied and adopted in order to maintain coal within the range of its economic boundaries.

Metallurgical Uses. Throughout the country in the metallurgical and the ceramic industries, there are many small furnaces today burning oil and gas largely because of the convenience of such fuels, and their cleanliness from ash and dirt. Some of these installations are justified, others are not. However, so far, adaptable pulverized equipment has not been available. The market has not seemed large enough for equipment manufacturers to go beyond certain limited efforts, and the coal industry has not been organized to aid seriously. Now these groups are awakening to the opportunities which may be available to place coal in this market effectively.

House Heating. The trend in the house-heating and domestic market is not altogether what it should be. Many of the small stokers leave much to be desired. We hear a great deal about "coke trees," ash removal, and slagging, which indicates that perfection has not been attained. Another point worthy of notice is that practically all domestic stokers are too much alike. There has not been sufficient inventive application to depart from something that is good enough and bring out a really superior article that inspires more competitive invention.

Coke and smokeless fuels from bituminous coal are likely to gain some headway.

Smoke Prevention. Another problem which is far from being solved is the smoke nuisance within our cities and built-up communities. Everyone in the industry should feel some degree of responsibility in that more has not been accomplished in this direction. The engineering branch is at fault for not having developed better equipment for house heating at a low price. The user is not free from blame, because oftentimes he has been too penurious and narrow-minded to buy equipment which was available, or to hire sufficiently skilled firemen and operators to get satisfactory results from that which he had installed or could install. The coal industry has been too lackadaisical because its members felt that they could not afford to make any more noise about the "sleeping dogs" than was really necessary. In many places, the smoke ordinances were allowed to lapse because prominent industrialists, or citizens, or others did not want them in force. Some have tackled the problem in reverse, trying to stop the smoke after equipment was installed which made smoke inevitable. However, there have been enough instances where the approach has been through the right channel of installing satisfactory equipment and enforcing the law to show that much has been accomplished.

Some mistakes have been and are being made. They can be corrected only if everyone will put his best efforts into doing whatever lies within his province as an engineer, as an owner of plants, as a coal producer, as a city official, and as a citizen. Whenever the subject comes up for a new law or a new regime, more words than facts are produced. We need more factual data as to the methods of preventing smoke. Oftentimes, the cost to the community has been exaggerated. The experts having differed on the nuisance value of one kind of smoke or dust compared with another, sometimes magnify the nuisance from the top of the stack and condone dirt and dust from streets, carried directly into our nostrils and eyes. We need intelligent consistency in solving this problem.

Processes. Again, looking into the future for an easy answer, some may say: "What about carbonization, gasification, hydrogenation, use of coal in internal-combustion engines? What about prepared-size fuels, such as briquettes, package fuel?"

The by-product coke process will undoubtedly continue. Among all the others mentioned, the author is more inclined to think that low-temperature carbonization or gasification in one form or another may be more economically developed. Internal-combustion engines are having difficulty enough to get along with anything but the best of gasoline or Diesel fuel. Direct use of pulverized coal in such engines or gas turbines does not now seem probable. There may be some special cases where coal can be so used directly, such as the Humphrey pump for pumping water, with limited application.

Hydrogenation, or the production of motor fuels in the liquid state from coal on an economic basis, is far in the future, regardless of what has been done in Europe or elsewhere.

It should not be overlooked that the by-product coke oven produces a highly refined processing of coal in which the high yield of suitable grades of coke is the principal product, and one that cannot be economically produced from petroleum. Among the many by-products of this process is a high-grade motor fuel, benzol. In 1939, this amounted to 79,000,000 gal, or about 0.2 per cent of the total motor-fuel consumption.

The processing of coal into coke, gas, and other products cannot be done except at an extra cost, and at a net loss in total heating value. It can be made to pay only if the resultant fuels and products are enhanced in value for special uses where raw coal cannot be economically used. The preparation of smokeless fuel through low-temperature carbonization has so far been difficult on an economic basis, but it is the more likely development next to the by-product coke oven.

It is not beyond the realm of possibility that coal will be burned in a better way than ever has been attained commercially, without gasifying, liquefying, or even pulverizing, and not in fuel beds as we know them today. There are, undoubtedly, many possibilities which no one has ever seriously considered in the handling of a valuable fuel like coal, but we are not giving them the attention they should have.

We might learn something from the petroleum industry which has expended vast sums in developing high-grade distillate fuels and usable cracked residues. Opportunities for chemical engineers in the petroleum industry were characterized in an article[1] some time ago, as follows: "Chemical engineers are well paid in the industry. However, working conditions may leave something to be desired. Oil is by nature a dirty, greasy, substance. Much of the work, at least in the early years, must

[1] "Opportunities in Petroleum Industry for Chemical Engineers," *Chemical & Metallurgical Engineering*, vol. 47, 1940, pp. 415–422.

necessarily require brawn as well as brains. Long hours may at times be demanded by the nature of the work or the keenness of competition. But oil, like printer's ink, gets in one's veins, and those who like it wouldn't live without it." Anyone who is familiar with the characteristics of crude oil, and has spent much time about oil refineries, would by straight choice pick up a lump of coal and say it was clean and easily dealt with, yet we must admit that the petroleum industry has forged ahead with conviction, intelligence, and persistence, and has attained many remarkable accomplishments, such as recovering more than twice as much gasoline from a gallon of crude as was recovered only a few years ago.

Petroleum is so difficult to use in its crude state that it has to be refined. Its carbon-hydrogen ratio is such that it is relatively easily processed into convenient grades of fuel. Coal may be handicapped by being usable in its raw state as well as it is, so that the urge to improve its clean and convenient use has lagged. Coal, with its higher carbon-hydrogen ratio, its moisture and ash, is difficult and at present unprofitable to process for motor fuels in competition with petroleum. Coal should be recognized as best adapted for the direct generation of heat, and our efforts should be concentrated toward transferring this heat value from the mine to its clean and effective use as cheaply as possible.

GENERAL COMMENT

In a general discussion[2] of the state of the industry, the author notes a tendency to admit that our present analyses and knowledge of coal are inadequate to evaluate it and, regrettably, to hold little hope for the future beyond practical tests in situ with a given equipment. A great deal of emphasis has been placed on the size of the coal, whether $^1/_2$ or $^3/_4$ in., and whether the moisture is "too high." It is our problem to develop coal-using equipment to minimize and entirely overcome these incidental variations in coal preparation. We need more faith that this can be done through further progress along the lines in which we are working. Equipment manufacturers would do well to strive toward a definite long-range goal. Keep on improving! Tear down and replace antiquated equipment as does the petroleum industry. The ideal coal-burning equipment has not yet been attained, but the author confidently believes that within a few years there will be better equipment which will make us wonder why we stayed bogged down so long with halfway measures.

In this changing period, the coal producer has a hard job. He must produce, size, and clean coal to suit a wide variety of equipment and specifications. Oftentimes the requirements are overly exacting because of the limitations or shortcomings of the equipment. Some of the newest stokers require the most exacting preparation. This is wrong. The right coal-burning equipment will take all grist which which comes to the mill and produce clean heat efficiently.

The author believes firmly that what is right will prevail. In visiting power plants 40 years ago, an important point of argument was whether or not mechanical draft should be used on a new boiler unit. There were advocates for natural draft, and also a few far-seeing engineers who saw the advantage of mechanical draft. Mechanical draft was right, and it won. Any of the larger boiler units going into our central stations today would have only a fraction of their present capacity if they depended upon natural draft.

The old debate between sponsors for beehive coke ovens and by-product ovens was settled by facts and time, and not by discussions and opinions.

Again, at about the same period, in locomotive practice, there was much debate as to whether or not arches should be installed in locomotive fireboxes. The argument is now all settled. They are installed in all locomotive fireboxes.

Still more recently there has been great argument concerning stokers and pulverized coal in large central-station units. The argument is now over and some of the stoker plants, burning the best of semibituminous coal, installed less than 12 years ago, have been changed over to pulverized coal. The owners consider the change the best investment they have ever made.

Waterwalls for large furnaces are now recognized as a necessity, as proved by facts.

Opinions do not count for very much; facts predominate. However, facts themselves do not come forth and become established without a sponsor. Someone must be visionary enough to see the possibilities of doing things a newer and better way, and have the courage of his convictions to bring them forth and establish them.

Just one more point, and that is the future with respect to the available supply of different kinds of fuel. Forty years ago, the oil supply was predicted to last only 20 years. Today, new fields are being found at a faster rate than oil is being consumed. However, the present known available supply is barely 10 times the 1940 production. Some of the optimists, who know this industry, feel confident that new discoveries will keep ahead of demand, so that there is little question in their minds but that oil will be plentiful 100 to 120 years hence. Whether that be true or not, we do know there is plenty of coal for many generations to come.

The future of civilization may depend more upon fuel than we realize. It may behoove us to conserve those fuels suitable for combat and protection, for use in tanks, airplanes, and naval vessels, hence, an added incentive to make better use of coal so that our future will be most secure.

[2] Consisting of papers and discussion at the meeting at which the present paper was delivered.

Views of Management, Labor, and Government

(Continued from page 294)

that representatives of both labor and management work with us on these matters.

An evaluation plan should include such factors as judgment or the mental effort required, skill, responsibility, working conditions, time to learn the job, physical effort, and hazard.

With such an evaluation if done correctly and consistently, the employer should then be able to set wage rates in his plant that will be accurate and fair. Whether wages are set according to a plan following job evaluation, or a wage index, the important thing is that every company should have a definite wage plan or policy. The plan the company chooses may not be the most scientific or they may not pay the highest wages, but there are fewer disputes or strikes when wages in a plant are determined on a consistent policy. Naturally workers resent another worker who is doing another identical job, and who is receiving more wages.

Summing up, the aim of this meeting has been to explore the field for some factual basis for establishing wage rates. From the various contributions made by the representatives of management, labor, government, and the public, I think we all fully realize the need for a definite plan within an industry and for all available factual aids in solving our labor-management problems whether it be by an index, by an evaluation, by comparison, or by guess or by gosh.

To industry I say, yes, I know how you feel as a company, but to you gentlemen as individuals, labor, and management, after all what's in the pocket on pay day is the thing, and that thing, wages, must be a fair rate for service or effort and passed on to me in an understandable way.

BRIEFING THE RECORD

Abstracts and Comments Based on Current Periodicals and Events

MATERIAL for these pages is assembled from numerous sources and aims to cover a broad range of subject matter. While few quotation marks are used, passages that are directly quoted are obvious from the context and credit to original sources is given.

20,000,000-Volt Electrons

A LARGE and powerful electron accelerator called by its originator the rheotron, opening up a new field for scientific exploration by its production of an electron stream far more penetrating than the electrons from radium, has been announced by the General Electric Research Laboratory.

This achievement is largely due to the work of Donald W. Kerst, and is based on an extension of his preliminary studies at the University of Illinois and on a small machine which he built there. By means of the new unit, electrons are accelerated to the highest speed ever produced by a man-made apparatus. It gives these particles energy corresponding to 20,000,000 volts and also produces X rays of this power.

Dr. Kerst, a 30-year-old physicist from the University of Illinois, built the new rheotron with the aid of G. E. engineers and scientists.

So promising have been the results obtained with the rheotron that the laboratory has already started work on a larger one to cost more than a quarter of a million dollars and designed to whirl electrons to an energy of 100,000,000 volts.

Though much more powerful than the towering machines previously used to accelerate electrons to high speed, the rheotron is a comparatively small device. The magnet of the present machine is only five feet long, three feet high, and two feet wide.

"The rheotron does for negative electrons what the cyclotron does for positive ions but does it in a different way," explains Dr. Kerst, "and, for a given voltage, is much smaller.

"A doughnut-shaped glass vacuum tube, between the poles of a large electromagnet, is the heart of the rheotron. Electrons from a hot filament within are whirled around the tube and steadily accelerated by electromagnetic forces until they attain a speed closely approaching 186,000 miles a second, that of light."

Dr. W. D. Coolidge, director of the laboratory, said that the rheotron provides an important new tool for fundamental research. "Hitherto, experiments with high-velocity electron beams have not kept pace with experiments done with positive ions from the cyclotron," he explained. "The cyclotron is incapable of accelerating electrons, and previous devices able to do so have seemed to reach a practical limit at something like half the voltage of the present accelerator.

"The rheotron seems to have no such limit and its effective voltage can apparently be increased indefinitely. It works, not by applying the entire voltage at once, but by building up the speed steadily throughout all revolutions. As a result electrons have already been given sufficient velocity to penetrate an inch of aluminum."

The present machine weighs about four tons. The pole faces of the two electromagnets which sandwich the doughnut-shaped glass vacuum tube are 19 in. in diameter. The tube has an outside diameter of 19 in., an inside one of 11 in., and is about 2 in. thick.

Since it is designed for use on alternating current, the magnet assembly of the rheotron is composed of thousands of thin sheets of silicon steel, instead of being of solid iron as in the cyclotron. Instead of circling the magnetic field by following a coil of wire, as in a high-voltage transformer, the electrons whirl around inside the doughnut-like tube, in which pumps maintain a vacuum.

Magnetically guided, each electron travels along a circular path for about 400,000 revolutions, receiving as much as 70 volts push each time around, and traveling some 200 miles in a small fraction of a second to gain a speed within a tenth of one per cent of that of light. By causing these electrons to collide with a metal target, X radiation equal in intensity, as determined by ionizing power, to the gamma radiation in a corresponding beam from more than 1000 g of radium, more than the world's existing supply, can be produced by the machine.

Felt Mountings for Machines

THE FELT ASSOCIATION, INC.

WAR-inspired changes in production routine have been simplified in many defense plants by the use of wool felt as a footing under machines, according to a release by The Felt Association, Inc. Where machinery must be rearranged to secure an altered flow of materials, the use of felt isolaters introduces marked economy, because in many instances it entirely obviates the need for drilling or patching floors, as many machines, when supported in resilient footings, do not have a tendency to walk away from the job, and hence require no permanent fastening.

Where positive anchorage is necessary, the use of selected adhesives, which have been developed by the several leading felt manufacturers who are active in this field, greatly simplifies matters. A special solvent readily loosens the bond between the machine and the floor, permitting its removal to a new location where it is again secured by an application of fresh cement. In fact, the felt may be attached to the legs or base of the machine only, and not to the floor at all; hence the possibility of effecting planned changes quickly and inexpensively.

Such a change, it is claimed, will work wonders in the way of quieting vibrations commonly produced by many kinds of machinery. Imparted to floors and walls by rigidly mounted machines, such vibrations are transmuted into noise by the resonance of the building itself and its equipment. Major vibrations from the same sources often cause buildings to sway and have a serious disintegrating effect on certain classes of building materials.

Vibrations transmitted from room to room and floor to floor in manufacturing buildings often have an adverse effect on delicate manufacturing operations. They are disturbing to precision instruments and often impair their performance. Proper control of vibration at its source, through isolation of the individual machines, therefore, is a valuable form of plant protection, as well as an improvement for the individual machine.

Felt manufacturers themselves were among the first to discover the advantages of wool felt as a vibration damper in machinery mounting, and to note with satisfaction some of the principal advantages of this substance compared with others which compete in the field of isolation. They claim that felt is unaffected by moisture, ordinary solvents, and moderate changes of temperature; also that it does not age or crumble under the influence of vibration. In other words, the mounting will last as long as the machine.

Information about the different classes of machines, on which felt mountings are being used, and results of extensive research on isolation can be obtained from The Felt Association, Inc., 366 Madison Ave., New York, N. Y.

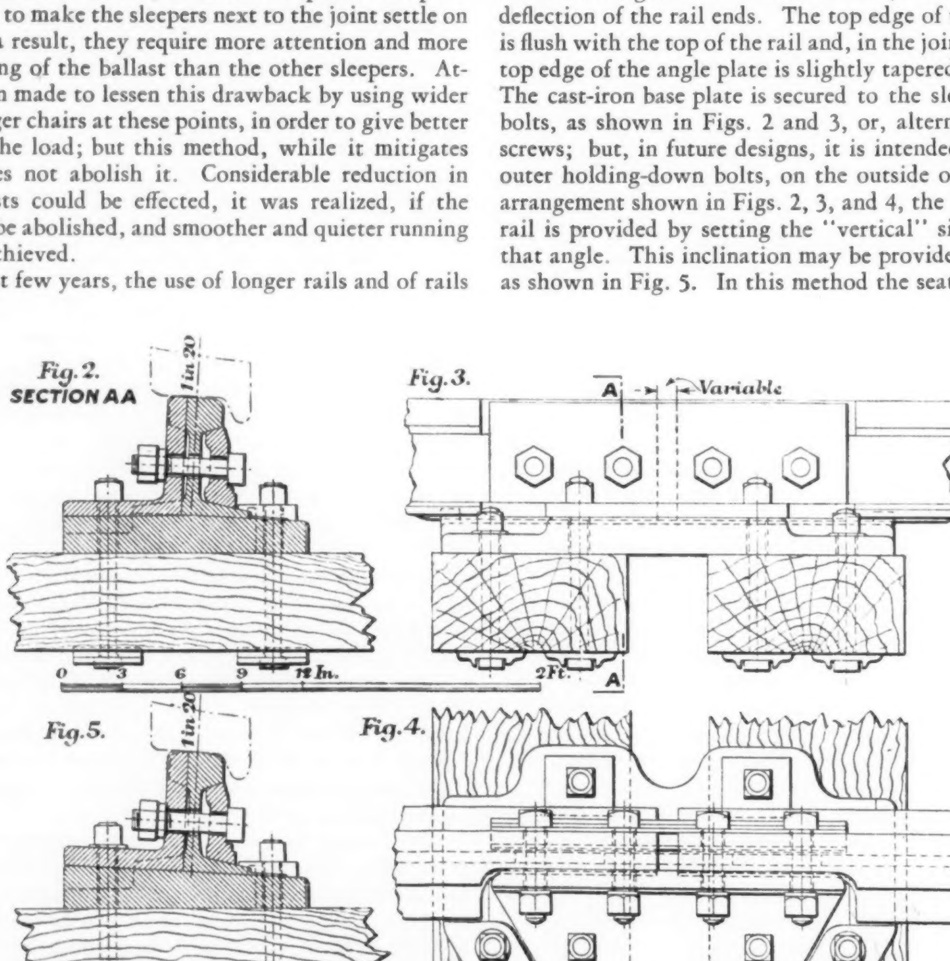
Rail Expansion Joint

ENGINEERING

DESCRIBED in *Engineering* for January 23, 1942, is a new form of rail expansion joint, designed by Mr. George Ellson, chief engineer of the Southern Railway (England), which is illustrated in Figs. 2 to 5. It has been designed to prevent the deflection of the ends of abutting rails between the adjoining supports which occurs under passing loads, and which gives rise to the pounding that is always experienced in consequence. The ordinary fishplate joint is necessarily weaker than the rails which it connects, so that the impact of the passing wheels tends to make the sleepers next to the joint settle on their beds. As a result, they require more attention and more frequent repacking of the ballast than the other sleepers. Attempts have been made to lessen this drawback by using wider sleepers and longer chairs at these points, in order to give better distribution of the load; but this method, while it mitigates the trouble, does not abolish it. Considerable reduction in maintenance costs could be effected, it was realized, if the pounding could be abolished, and smoother and quieter running would also be achieved.

During the last few years, the use of longer rails and of rails welded together in even greater lengths, has been experimented with on a fairly comprehensive scale on various British and foreign railways; but it has been found that an appreciable increase of cost is incurred in the rolling or welding, and in the extra handling entailed. Moreover, where long lengths of rails are laid, the expansion gaps, where these still occur, must be considerably greater than with normal rail lengths; and ill effects arise if the ordinary type of fishplate joint is used. With the new construction, the full strength of the rail is maintained across the gap; and as the spacing of the adjacent sleepers is less than the spacing elsewhere on the track, the strength of the joint as a whole, considered as a beam, is actually greater than that of the rail as laid at the ordinary sleeper intervals. The deflection of the rail at the joint, therefore, is less than at any other point. Further, as the wheel track is continuous over the joint gaps, the pounding experienced at the ordinary joint is eliminated.

The method of forming the joint will be clear from Figs. 2, 3, and 4, from which it will be seen that the ends of the abutting rails are recessed on the outside by machining away the head and foot. In the recess thus formed, there is fitted an angle bridging piece of rail-quality steel, which constitutes the outer fishplate. A fishplate of standard type is fitted on the inner side. The angle plate and the ends of the rails bear on a cast-iron base plate; thus, the load is transmitted over the joint gap by the complete assembly of angle plate, inner fishplate, and base plate. As the strength of these three elements is equal to the full strength of the unbroken rail, there is practically no deflection of the rail ends. The top edge of the angle fishplate is flush with the top of the rail and, in the joints now in use, the top edge of the angle plate is slightly tapered down at its ends. The cast-iron base plate is secured to the sleepers by through bolts, as shown in Figs. 2 and 3, or, alternatively, by coach screws; but, in future designs, it is intended to omit the two outer holding-down bolts, on the outside of the rail. In the arrangement shown in Figs. 2, 3, and 4, the 1-in-20 cant of the rail is provided by setting the "vertical" side of the plate at that angle. This inclination may be provided in another way, as shown in Fig. 5. In this method the seat on the base plate



is given an inclination of 1 in 20 above the horizontal, which enables a standard angle cleat to be used as the outer fishplate. The joint can be applied to both bull-headed and flat-bottomed rails.

On test lengths of track it has been found that, besides the elimination of noise at the rail joints, creeping of the rails has been abolished, and the sleepers nearest to the joint require less packing than the others.

Larger Welding Rod

If instead of continuing arbitrarily to use the smaller diameter rods, industry would employ just one size larger, there would be a tremendous increase in speed of welding and, consequently, much faster production of vitally needed welded war products, according to J. F. Lincoln, president of The Lincoln Electric Company. For example, every welder working today who would start using $^1/_4$-in. electrode in place of the $^3/_{16}$-in. size, could, in six hours, do the same amount of welding he now does in eight. The total saving in man-hours, if only half the 200,000 welding operators were to make this change on only 50 per cent of the war welding jobs being done today, would be equivalent to 25,000 welders. This army of workers would thus be made immediately available for other, or additional, welding work.

Electrodes of larger diameter, says Mr. Lincoln, make for faster welding because they deposit more metal in a given time than the smaller sizes. Larger electrodes simply "pour" the metal into the weld faster than small ones.

Not only would adoption of larger electrodes give industry a new and vast army of skilled welders, but it would relieve a threatened bottleneck in electrode production. According to Mr. Lincoln, it takes just as long to produce small-size electrodes as it does large ones. The controlling factor is the application of the coating which allows the modern electrode to produce the much higher quality of weld than was possible with old-type uncoated rods. If the welding industry could concentrate on producing larger size electrodes, the availability of electrode metal would be greatly increased, since the larger sizes contain proportionately more metal for welding than the smaller.

Magnesium in Wounds

INDUSTRIAL MEDICINE

A NEW danger threatens workers in war industries, in the form of gas gangrene caused by the infection of open cuts or wounds with the dust, spicules, turnings, swarf, and metallic fumes of magnesium or its alloys, according to an article[1] in the February, 1942, issue of *Industrial Medicine*.

The danger from magnesium lies in its capacity to liberate hydrogen from water and other hydrous fluids such as physiologic saline. Thus, minute quantities of magnesium in a cut result in the formation of gaseous cysts which cause necrosis of the adjacent tissue. The paper describes the experimental procedure and results obtained in implanting various light metals and alloys in rabbits and white rats. Photographs and radiographs illustrate the progress of the resulting gaseous tumors.

In this country there is no known published information on the effects of magnesium in humans, but it is understood that many cases of gas gangrene have occurred in German industries.

The authors summarize their report as follows:

Light metals and particularly magnesium, on contact with aqueous fluids, liberate a gas both in the body and in vitreo. Puncture wounds from metallic magnesium or some alloys may, because of the phenomenon just mentioned, lead to injury of a type more severe than ordinary foreign-body injuries. Under experimental conditions, less than 100 mg of metallic magnesium produced within from 24 to 36 hours single or multilocular gaseous tumors yielding on puncture near to 5 cc of gas. Initially the gas is believed to be hydrogen, but through diffusion and admixture other gases come to dominate the chemical analysis. The clinical picture is one of chemical-gas gangrene or necrosis. Actual human experience in the United States is limited or at least not known to have been published, but in case of puncture wounds unfailingly it becomes the duty of the attending physician to remove all portions of the gas-liberating magnesium.

[1] "Chemical Gas Gangrene From Metallic Magnesium," by Carey P. McCord, M.D., of the Industrial Health Conservancy Laboratories, and John J. Prendergast, M.D., Stuart F. Meek, M.D., and Gordon C. Harrold, Ph.D., of the Chrysler Medical Department and the Industrial Hygiene Laboratories, Detroit, Mich., *Industrial Medicine*, vol. 11, February, 1942, p. 71.

Australia's War Effort

A dinner meeting of the Chicago Section, A.S.M.E., on November 26, 1941, at which members of other scientific and technical organizations were guests, was addressed by Sir Herbert Gepp, eminent engineer and industrialist of Australia. The subject of Sir Herbert's address was "Australia's War Effort as a Member of the British Commonwealth of Nations." He said in part:

When, after the strainful and stressful years of 1935–1939, the inevitable happened and the challenge to Hitler's policy of conquest was finally made by the British Commonwealth of Nations and France, there was no question in the minds of the Australian people. According to the Statute of Westminister, each member of the British Commonwealth of Nations has the right of determining for itself whether it will follow the lead of the Mother Country and declare war. As you know, every member of the British Commonwealth has declared war, with the sole exception of the Irish Free State. Australia did not hesitate. Parliament declared war within a few hours of the declaration by Great Britain, and after the recent change of our government in Australia a declaration was made by our new Labor Prime Minister, that Australia was in the war for keeps and for victory, with wholehearted determination and without reservation.

Geographically, the United States and Australia are the same size—approximately three million square miles. You are north of the equator and we are south.

Climatically, you have much advantage over us. Out of your three million square miles you have two million four hundred thousand that are more or less suitable for agriculture. We have but seven hundred and fifty thousand square miles out of our three million. Again, out of your two million four hundred thousand square miles, you have some eight hundred thousand square miles with a rainfall of over forty inches; while we have only eighty thousand square miles. In other words, you have ten times as much area with a high rainfall as we have. Our waste and spare land is twelve thirtieths of our total area, while yours is only three thirtieths. On the other hand, our pastureland, particularly for sheep, is one third of our total area compared with one tenth in your case. However, much of our pastureland will carry only one sheep to fifteen acres. You can now see one of the reasons why with three hundred years of development you have a hundred and thirty million people while we, with a hundred and fifty years of development

have only seven million people. But do not forget that in addition to the seven million people, we have one hundred twenty million sheep and many other animals also.

Geologically and topographically also, you have much the advantage over us. Providence has given you huge mountain ranges, much good soil, and your country is such that the departure of your rainfall year by year from the average is one of the least in the world. It is often unrecognized that when you come to consider the possibilities of rainfall in areas approaching the marginal condition of rainfall, the average figure is dangerous and misleading. If this had been recognized in Australia then many valiant efforts to develop our land agriculturally would not have been made because later it was realized that if you have too many years of low rainfall balanced by a few years of high rainfall, the years of low rainfall will be disastrous to the economics of settlement. It was not until the Development Commission, of which I was chairman for a number of years, drew strong attention to this important point that it was taken into national consideration.

A continent which had laid almost entirely dormant for centuries while adjacent areas such as Java were teeming hives of activity should surely have said silently but eloquently to the people who came from the northern hemisphere to occupy and develop this strange, silent, and rather forbidding land, "Had you not better carefully think why I am undeveloped?" Such a large land mass as the Australian island continent would have been developed and populated hundreds of years ago if circumstances had been propitious and knowledge sufficient. The fact that it has remained unpopulated, relatively speaking, promised great difficulties to the pioneers who tackled the job. It is perhaps as well that they did not fully recognize this fact.

The earliest Australians had to cut and try. They had no precedents. They had to discover that in the main agricultural areas of the continent there was a remarkable and almost unique absence of phosphates in the soil. They had to find that whereas in England five hundredweight of phosphatic fertilizer was used regularly on the soils that had been worked for hundreds of years, with the low rainfall condition in Australia, less than one hundredweight would more than double the yield of cereal crops and of pasture grasses.

And then in the early eighteen fifties, alluvial gold was discovered in Australia, fabulously rich. This strange old continent had been worn down over millions of years by rain and sun and wind until the greater part of the interior was a vast plain called by geologists a peneplain about one thousand feet above sea level. The elements had exposed the mineral-bearing rocks and, in the earlier geological periods when rainfall was high, the rain had washed the gold from the auriferous reefs into the river beds. This discovery led to a tremendous influx of people—of the adventurous spirits of the world. Gold was there for the finding and the Forty-Niners of California led the procession. There again we have another inheritance from your country. Perhaps some of the drive that we have came from the descendants of the gold seekers who migrated from the west coast of America by sailing ships to the Australia of 1850–1860.

With the birth of the national spirit after the last war, when our nation was blooded and welded into a unity, there came a determined effort to hold up the strength of Australia not only in agricultural and pastoral pursuits but in secondary industries utilizing the resources of the continent—the minerals, the timbers, and the raw materials for textiles, and all those cognate industries that flow from the basical key industries.

Fortunately, we had in charge of these various rich developments men who reserved from dividend declarations considerable credits which, together with new capital, were invested in other industries of the commodity type. Thereby sprang into existence iron and steel works based upon the iron ore and the high-grade coal deposits of the eastern seaboard; the textile industries, close to the great cities, based upon the famous woolen production of Australia, the cotton fields of Queensland, supplemented by, to date, the importations of artificial silk. After many years of expensive experimentation, we have found out how to use the hard woods of Australia for making paper pulp and paper. We have no soft woods because although we know from our deposits of coal and of brown coal that pines and firs and spruces grew in Australia, they no longer exist in commercial quantities and our forests are practically all of hard woods.

It is interesting to note the two different directions in which the labor movement of the United States and of Australia moved. Under the influence of Samuel Gompers, labor in the United States did not form a distinct political party, whereas from the beginning of the movement in Australia some fifty years ago, the leaders of the labor movement determined to achieve their objectives one by one by political action. I would not care in such time as I have at my disposal to make any comparisons or direct comments. But it is interesting to observe that the early drive of the Australian labor movement toward political significance led to the development of legal recognition of the system of conciliation and arbitration. State and Federal courts were constituted by acts of Parliament; judges and conciliation commissioners were appointed for long periods, if not for life. Minimum wages were established and legal variations determined on the cost of living became a portion of the law of the land. Labor unions were registered with the courts, and the leaders of these unions, slowly but surely, developed a sense of responsibility, encouraged by the necessity of arguing their cases before permanent judges removed from the common stress and strain of living by permanent appointments with assured recognition and future security.

Knowing from their particular experience of the war in 1914–1918, I think it is correct to say that Australians had no illusions of what was really to happen in general when war broke out in September, 1939. We knew the genius for organization of the German leaders; we knew the ability and subservience of the German people. And as soon as the collapse of France came we woke up. Previously we had been in the daydream in which all the other democracies were slumbering, wistfully thinking that somehow or another all would be well.

Fortunately for the Empire, for the democracies of the world, and for ourselves, the twentieth century from 1920 onward had seen a remarkably rapid growth of Australia's ability to contribute substantially to the war effort. Our population had increased by nearly two million people. We had established many of the basic industries—iron and steel and zinc, paper and textiles, and aviation. We had expanded many of our other industries, we had sent many of our people overseas, we had improved our contacts with other countries, and significantly we had again welded the people together by our fight in the depression years of the early thirties to retain our good name by maintaining our financial integrity overseas. We had voluntarily and to a slight extent compulsorily cut the rate of interest on all internal government bonds and stocks. We had, through our arbitration courts, subsequently obtained a ten per cent reduction in all our wage rates, paralleling the reduction of twenty-two and a half per cent on our interest rates on government indebtedness. This decision of the Federal Arbitration Court was given after the reduction in interest rates and was accepted by the working people of Australia without a single strike.

We have, as you have, compulsory service for our youth for home defense; we have voluntary enlistment for overseas service.

Ships of the Royal Australian Navy, working in conjunction with the ships of the Royal Navy, have convoyed thousands of troops and hundreds of thousands of tons of material overseas. They have played a prominent part in the Mediterranean naval war and in the Pacific Ocean. A number of our merchant vessels have been converted into auxiliary cruisers. More than two hundred merchant vessels have been defensibly armed in Australian dockyards, and gun crews have been provided and trained by the Royal Australian Navy.

In conjunction with the Navy, the Royal Australian Air Force, co-operating with the Naval and Air Forces of New Zealand, are operating also in the Pacific Ocean.

As in this country, factories are springing up all over the continent. I was in a government munitions factory, just before I left Australia in September, that I have known as a small nucleus plant ever since I was the manager of an explosives works in Australia in 1900. I went through this factory in September last and saw such a growth as was astounding. There were 17,000 men and women working in that factory three shifts a day, seven days a week. I went through two aircraft factories, which four years ago did not exist, and which now employ in toto over 12,000 men.

Under the drive of necessity we are building all types of ammunition from small-arms to large shells, all types of guns up to field guns and howitzers, ships of ten thousand tons, and corvetts of eight hundred fifty tons. For example, we are making every month great numbers of rounds of small-arms ammunition and large quantities of trench-mortar bombs. We are conserving our gasoline resources and storing them against eventualities. My own Chevrolet car is allowed six gallons per month and we use instead charcoal gas producers. These cost, to fit onto an ordinary car, three hundred dollars or less. Just before I left Australia, I visited one of our mills and made a round trip of 250 miles using 200 lb of charcoal and a gallon and a half of gasoline.

We could not get new optical glass for range finders and other defense purposes from overseas so our scientific men got busy and we developed the process and are making our own optical glass. We discovered that, owing to the millions of years of leaching the sands and clays by rain in Australia and to the small amount of volcanic action which has occurred, we have the finest sands and clays for glass manufacturing that the world can produce.

With the development of radio and the presence in Australia for many years of associates of Marconi, we have been able to expand rapidly our factories for making radio instruments so that today we are producing all the radio equipment required by the fighting services on the sea, on the land, and in the air.

We are exporting millions of woolen garments, millions of pairs of boots, hundreds of thousands of other articles of apparel all for the use of the fighting services. Our food-stuff manufacturers are commandeered for war service and a great portion of our production is going overseas to the fighting fronts.

We are, as I have told you, only seven million people; but we are turning our country, as rapidly as we can, into a full-time arsenal for the East. In this way and owing to our geographical situation in relation to the eastern war fronts we can supplement the much greater and wider effort that your own country is making toward the same common end. It is officially estimated that five out of six of the men in Australia between eighteen and forty-five years of age will ultimately either be under arms or engaged in war industry. We are determined to fight and endure until we have won full assurance of future security and the freedom to worship and think as we so may decide of our own free will.

And what of the future? We older people owe it to our descendants to do our best to leave a better world in which to live.

Part of the war effort is to think continuously, constructively, and intensively about the reconstruction which must take place in all the democratic countries of the world when peace again comes.

Much good thinking about the shape of things to come—about "Where do we go from here?"—is being done in all the democracies. But there is little or no co-ordination—no one of us knows what the other is doing. We have an International Labor Organization meeting in New York. We have an excellent Round Table gathering organized and publicized by the magazine *Fortune;* we have serial discussion articles in the best of the English press—in so far as the shortage of paper in Britain permits.

What is urgently necessary is a general staff for postwar reconstruction with representatives thereon of each of the democracies and of all such other governments as are willing to join. Whether this is organized by the International Labor Office or not, it is essential that ample funds be provided and that necessary support be given by governments and all the people so that there may be gathered together immediately some of the best brains from the different democracies. This general staff would then be able to set out clearly and definitely suggested plans for the future, which could form the basis for postwar reconstruction.

Preparation for peace, as well as for war, is necessary. If we all had realized what was going on in Europe in preparation for war, the present position would not be so serious.

Back sight foremost is the deadly enemy of safety. We all have excelled in postmortem diagnosis in the past; but strange as it may be, we have not applied the observed results so as to prepare for the future.

Those masters of aphorisms, the French, have a saying that courage is ninety per cent experience.

With what we have gone through of recent years, we should be fortified with plenty of courage by now. It is our job to combine foresight and common sense with this courage, and think out and devise the readjustments and the common-sense compromises so that we shall know what to do when this dreadful war is over.

The greatest weakness of individualism and democratic systems of government is the fact that they have not so far been able to achieve victory over the economic disease of unemployment. Unemployment is the venereal disease of democracy, and if individualism is to remain in our system of life we must find a cure.

This cure must not be based upon paternalism or upon a policy of "bread and circuses." It is an old rule of life that if a man is able to work and will not work, he cannot eat.

Any compromise arrangements which are not based upon efficiency and the danger of the dole will in the end be sterile of results.

Compromises are often sterile, as the horse and the donkey recognized when they produced the mule. Like mules, compromises sometimes have a back-kick in them. However, compromises are available which are useful and productive, and the future of life upon this world depends upon the development of a system which will aim successfully at the improvement of the standard of life. We have to remember that the wealth of a nation does not necessarily depend upon any particular abundance of natural resources. It depends a great deal more upon the character and ability of its citizens. Scotland is an example of this truth.

In making a statement for the press in Australia in March of 1937, in connection with the necessity for a Youth Employment Survey, I said, "Any nation that does not study its social and financial systems and make all necessary modifications to

enable it to steer between the Scylla of mollycoddling its youth and the Charybdis of rendering its youth desperate by the absence of logical employment and of opportunities for the development of mental and physical characteristics will in the end suffer eclipse. It is unthinkable that democracies can permit of an indefinite continuation of conditions under which a material proportion of its growing population is seeking employment and finding none. . . . This problem has many aspects extending from the need for vocational training to the study of the causes of falling birth rates and to the spreading of knowledge and application of the rules of nutrition."

There are numerous problems which all democracies must attack with a unity of purpose. Unity of purpose internally within each nation and externally between the nations is essential. It is important to instill into all the citizens an inherent and instinctive appreciation of democratic principles. It is essential that the citizens recognize the danger of power in the hands of any man without the corresponding responsibility. This was the invariable view of your great leader, Thomas Jefferson.

We must endeavor to find a working compromise between freedom and equality, which are primarily incompatibles.

I want to suggest to you that no real democracy can exist without an aristocracy as part of that democracy. I mean that no democracy can exist without leaders and unless at least directed by a working motto of noblesse oblige—a sense of public duty for its own sake.

War Output to 2000 Per Cent

NATIONAL INSTITUTE OF INDUSTRIAL PSYCHOLOGY, LONDON

OUTPUT of shell fuse cases in a British munitions factory was increased twentyfold after industrial psychologists had suggested improvements in methods of working.

The job required careful hand-soldering of seams, and as the factory had lost most of its experienced help the weekly output was only 1000 good cases, with several thousand rejects. But after various changes of which the most important was a systematic training scheme, based on careful study of hand and body movements, the output was raised to 20,000 cases a week, passed by the inspectors.

This is only one of the cases in which trained psychologists from Britain's National Institute of Industrial Psychology have helped to speed up production in Britain's war factories. Although the results are sometimes startling there is no particular magic about their job. It is based rather on a careful study of the physical movements entailed, on proper methods of instruction, and above all on interesting the trainee in the work.

Training is made interesting by interspersing handwork with general instruction so that trainees understand how their work fits into the general scheme. In weaving, for example, they are told about the types of thread used, the use of the cloth which is being woven, and so on. In tank factories they not only see their particular part assembled into the completed job, but are shown the tank in action.

Coil-winding operatives trained by these methods were found to reach a standard of proficiency in only five days which previously had taken five weeks. Moreover, this was not achieved at the expense of output, for a 65 per cent increase in the average output of good pieces was obtained, while the scrap rate fell from 5 to 2 per cent.

Apart from this, the psychologists have increased production by suggesting improvement in working conditions, amenities, and by investigating and smoothing grievances.

High Pressures

THE SOCIETY OF THE SIGMA XI

THE problems and techniques of high pressure as developed in the laboratory, eventually to a pressure of 400,000 atmospheres, and some of the effects of high pressure were discussed by P. W. Bridgman, Hollis professor of mathematics and natural philosophy at Harvard University, in recent lectures at a number of colleges and universities under the auspices of the Society of the Sigma Xi, national fraternity for the recognition of scholarship and the promotion of scientific research.

Dr. Bridgman described the steps by which controllable and measurable laboratory pressures have been successively raised from the previous value of 3,000 atm or 45,000 psi, the maximum employed in artillery, to the eventual figure of 400,000 atm or 6,000,000 psi. The latter is the pressure that would be found under a tower of bricks nearly 1500 miles high, or at a point in the interior of the earth over 1000 miles below the surface. Long before the tower could be built to its immense height, it would be crushed by its own weight. And even if it were not, it would crush the hardest rocks on which it might stand.

Even under this enormous pressure, graphite refused to change to diamond, and Dr. Bridgman believes that no pressure, however high, would bring about the transformation under ordinary temperatures.

Boiling-hot ice was produced at a much lower pressure. In fact, at a pressure of 40,000 atm, ice was produced at a temperature of approximately 375 F. This is 163 deg above the usual boiling point of water, nearly as far above it as the boiling point is above the freezing point.

Hot ice is possible because at a certain point with increase of pressure, ordinary ice is suddenly changed into a different form which sinks in water instead of floating, whose melting temperature is therefore raised instead of lowered with increasing pressure.

All substances, Dr. Bridgman finds, except those of the simplest internal structure, undergo these sudden changes at certain temperatures and pressures, some of them many times within the available ranges. Thus, up to a pressure of 50,000 atm, there are seven different kinds of ice, all of them except ordinary ice heavier than water. In this range there are eleven kinds of solid camphor and six kinds of bismuth up to 100,000 atm.

All of these transformations are reversible. As the pressure is lowered, the preceding forms are restored. But Dr. Bridgman has found two transformations that are not reversible. At 12,000 atm and about 392 F, yellow phosphorus is permanently changed into a black form which is much like graphite in its properties. At 40,000 atm and 347 F, the clear liquid, carbon bisulphide, is permanently changed into a black solid.

The electrical conductivity of substances is changed by pressure, especially in the case of poor conductors. At 30,000 atm, the conductivity of tellurium is 600 times its value at atmospheric pressure. For good metallic conductors, the increase is only up to about seven times at 30,000 atm. On the other hand the conductivity of about a quarter of the metals diminishes continually up to this pressure, while for several the conductivity at first diminishes, then increases. Dr. Bridgman thinks it not impossible that at sufficiently high pressure the conductivity of all metals will eventually decrease, but this could not be confirmed because it was impossible to get insulated electric wires into the pressure chamber at the higher pressures.

COMMENTS ON PAPERS

Including Letters From Readers on Miscellaneous Subjects

Progress in Railway Mechanical Engineering

To the Editor:

Your March issue carries a letter signed "R. Roader," praising the Railroad Division's 1941 report on railway progress and lamenting the lack of railroad men in the Railroad Division. The appearance of this letter causes me much surprise. Surprise that a railroad man should have attacked the Railroad Division anonymously. Surprise that you should have published his erroneous statements without comment.

Let us look at the record. After praising the report as a "notable addition to railroad literature," your anonymous correspondent finds it sad that of the three authors of the report "only one . . . is a railroad man." The report was prepared by a committee of three selected to give the widest possible coverage to railway progress. One is professor of railway mechanical engineering, one is chief mechanical officer of a large western railroad, and the third is a high authority on electric traction on railroads. The quality of the report is full justification of the wisdom of choosing a broadly representative committee.

Your correspondent, saddened by the fact that only one "railroad man" was a co-author of the report, finds it "more sad" that in the executive committee of the Railroad Division "less than half . . . not including the present chairman are railroad men." These are weasel words, conveying a false impression. The Executive committee has five members. The chairman and two other members are railroad men. Another member is mechanical engineer in the Bureau of Safety, Interstate Commerce Commission. The energy of the fifth member is responsible for the addition of dozens of railroad mechanical engineers to the roster of the division in the last few years.

Another cause of sadness to your compiler of "melancholy statistics" is that of the ten past chairmen "only two were railroad men." This again is incorrect. Of the ten gentlemen who filled the chair from 1932 through 1941, five made their mark as railroad men, one was a professor of railway mechanical engineering, and one was the editor of *Railway Mechnical Engineer*.

The complexion of the present general committee of the division should have pleased our critic, but he overlooked it. Of its sixteen members, ten are "railroad men."

Had he realized this, your unknown Jeremiah could hardly have ended his letter as he did: "It seems too bad, however you look at it." May I suggest that the Railroad Division does not look bad if looked at in an intelligent, broad-minded way. The purpose of the division is to provide a common meeting ground and open forum for all engineers, irrespective of their affiliations, who are interested in the mechanical problems of railway engineering. The field is broad, and many workers of diverse points of view are needed if it is to be thoroughly cultivated. The Railroad Division aims to secure on its directing committees proper representation of mechanical engineers in railroad service, in government service, in academic work, and of those engaged in the manufacture of railroad materials.

It is unnecessary to argue the case of the government and the academic engineers. But if "R. Roader" will stop, look, and think, clear the cobwebs out of the brain and the cinders out of his eyes, he will realize that there is advantage to all concerned in having a close co-operative contact and free discussion between his favored "railroad men" and the supply engineers. Mechanical engineers in railroad service are of necessity general practitioners. They must deal with locomotive design, steam generation, car design, lubrication, feedwater treatment, air-brake engineering, and dozens of other phases of engineering work. The engineers of the supply companies are specialists. Each can devote the major part of his effort to one particular branch.

There is obvious advantage in providing an opportunity for free exchange of ideas between those who know something about a lot of things and those who know a good deal about a few things.

In conclusion may I protest against "R. Roader's" rather Pharisaical use of the phrase "railroad men" to designate only the railroad-employed engineer. Let him rather recognize that all of us, those working for the railroads and those making things for railroad use, are vitally interested in the success of the railroads, and that in the best sense of the words we are all "Railroad Men."

Lawford H. Fry.[1]

[1] Railway Engineer, Edgewater Steel Company, Pittsburgh, Pa. Mem. A.S.M.E.

Watts Bar Power Station

Comment by G. E. Morgan[2]

The authors point out early in the paper[3] that with a predominantly hydroelectric system it is comparatively easy to overcome steam-plant outages by hydrospinning reserve units. It is agreed that cutting such hydrounits into the system for ordinary short outages of steam units of nominal capacity would have little appreciable effect on reservoir storage, and, even if the steam-unit outage were longer than anticipated, it is agreed that, when brought back into service, steam units could be run a little longer to compensate for the depletion of reservoir storage. However, the writer believes it logical to assume that such steam-unit outages are more likely to occur in some of the older acquired or leased plants than in the new Watts Bar Steam Plant. In fact, such an outage recently occurred affecting the 60,000-kw unit in the Sheffield plant. This particular unit is a cross-compound machine of one high- and two low-pressure turbogenerators, each of 20,000 kw capacity (approximately 250 psi and 50 psi, respectively). While both low-pressure units were operated for a short time, it was also necessary to take one of them out of service for repair, so that during most of the outage time, an average of less than 20,000 kw was generated. This outage lasted about 12 weeks. It will be agreed that this

[2] Mechanical Engineer, Charles T. Main, Inc., Boston, Mass.

[3] "The Watts Bar Steam Power Station of the TVA," by G. R. Rich and R. T. Mathews, Mechanical Engineering, November, 1941, pp. 773–779.

incident would have been more serious if considerable rainfall early in July had not made it possible to stop the voluntary curtailment of power usage then in effect, and if it had been a single-shaft machine of the same capacity.

The capacity of this unit is 30 per cent of the total of 200,000 kw of the acquired or leased steam capacity, and the Authority has anticipated a recurrence of such a condition in this or other old plants by asking for authorization for a fourth 60,000-kw unit for the Watts Bar Steam Plant, which authorization is expected shortly. The new unit will, of course, be a duplicate of the three units already purchased for Watts Bar, and its capacity just happens to coincide with the capacity of the older unit at Sheffield.

The authors have pointed out that, in an extremely dry year, all of the steam plants may be required to operate for 37 consecutive weeks. Extremely dry years may be several years apart, but they may also be consecutive or close enough together so as to affect the "flywheel" of reservoir storage.

Referring to the subject of heat balance, it will have been noted that the first two units are cross-connected with high-pressure steam and boiler feedwater piping. The original authorization was for only two 60,000-kw units with the third unit probably required only after several years. The design had progressed rapidly on this basis, and as at that time the new station was considered purely stand-by, the cross-connection was designed to increase the stand-by capacity of the two units by approximately 10,000 kw, should one of the two boilers have to be taken out of service, but with the two turbogenerators remaining on the line.

When it became evident that the third and possibly a fourth unit were required, and that the station would operate for a greater number of hours per year than originally planned, some of the firm stand-by features of design could have been eliminated for the third and possible fourth unit.

It was decided not to eliminate them, however, and, if the fourth unit is installed, the cross-connection between it and the third unit will increase the stand-by capacity of these two units by approximately another 10,000 kw, or a total of 20,000 kw for the station. This 20,000 kw of capacity is equal to the rated capacity of any single steam-turbine generator in the old acquired or leased steam plants.

The balance of the paper is generally confined to a description of the plant and its operation. It has been the intention of this discussion only to point out that the 180,000 kw capacity in the new station is but a trifle over 9 per cent of the system's rated capacity, and that it is 84 per cent of the entire acquired or leased steam-plant capacity. Further, all of the steam plants, including Watts Bar, will still have only approximately 20 per cent of the TVA system's total capacity. During the emergency of extreme dry periods and extreme floods with high tail water, all of this 20 per cent of capacity may be called upon to furnish energy to the system for long periods, as pointed out by the authors. In fact, during August, 1941, older steam plants supplied 24.2 per cent of the total generation which represents approximately 53 per cent of the total steam-plant capacity. Under these conditions, the reliability of even the older steam-plant units becomes considerably more important than might be assumed by emphasis of the spinning reserve capacity of hydrounits under normal, or nearly normal, conditions of river flow and reservoir storage.

Modern Shell Forging

COMMENT BY F. G. SCHRANZ[4]

In their paper[5] the authors stated that a more recent and successful shell-forging process is performed on the Baldwin-Omes mechanical shell-forging machine than was formerly accomplished.

The first machine of this type was built by the Skoda Works of Prague under license of Eumuco about 1935. The Woolwich Arsenal of London had several of these machines in operation at the outbreak of the European war. The Ordnance Department, U. S. Army, knew of these new Omes shell-forging machines and, having had favorable reports of their performance, was desirous of having units built and tried in this country. As a result the Baldwin Southwark Division of The Baldwin Locomotive Works acquired the license from The Omes Continental, Ltd., The Hague, Holland.

These machines are built in two sizes as follows:

The CM-50 machine for shell forgings up to 105 mm is a single piercing-and-drawing press, making a pierce and draw simultaneously with every stroke of the press crankshaft at the rate of 160 per hr.

The larger unit for shells up to 155 mm consists of a PM-75 piercing machine and a DP-20 drawing machine, producing 60 large shells per hr.

When the Pressed Steel Car Company of Pittsburgh bid on a contract for shell forgings, the Ordnance Department, U. S. Army, expressed the desire to have the Omes forging process used. That company now has some of these machines in operation on 105-mm shells. These machines are producing thousands of forgings per day with only a very small percentage of rejections.

When The Baldwin Locomotive Works received an educational order for steel forgings of 155-mm shells, the U. S. Government purchased the large double unit, PM-75, DP-20, and on this unit 5000 forgings were made with only 13 shells rejected.

The Australian Government ordered eleven CM-50 units and two PM-75, DP-20 units.

Eumuco, Ltd., of London also purchased from The Baldwin Locomotive Works two large units for one of its English customers.

[4] General Manager, Baldwin Southwark Division, The Baldwin Locomotive Works, Philadelphia, Pa. Mem. A.S.M.E.

[5] "Modern Shell Forging and Torpedo-Body Production," by A. B. Cudebec and Erwin Loewy, MECHANICAL ENGINEERING, November, 1941, pp. 783–786.

Aircraft-Engine Parts

To the Editor:

During discussion of a recent paper[6] by the writer, a series of questions was asked, the answers to which will now be given. In the following, each question is numbered, and the reply is given in the succeeding paragraph:

1 Can the transfer machine hold the required accuracy?

Yes. The proper location of the parts is assured by means of dowels which engage in bushings in the hardened carrier plates, which in turn are clamped tightly to the hard-steel ways. The unit heads are also mounted on hardened ways.

2 What was the length of time required to design and build the machine?

Approximately one year.

3 How is the first operation performed on the cylinder head?

The flange at the base of the head is faced and turned in a turret lathe, the tops of the rocker boxes are milled, the thread diameter is rough-bored, and the dome is finish-formed in a Bullard Mult-au-matic vertical lathe.

4 What is the schedule of maintenance, and what means are there of indicating tool breakage?

[6] "Mass Production for the Aircraft-Engine Industry," by H. E. Linsley, MECHANICAL ENGINEERING, vol. 64, February, 1942, pp. 100–105.

This is somewhat difficult to answer since the schedule will vary with each individual tool, with the degree of accuracy required, and with the difficulties inherent in each particular operation. For example: A small-diameter tap in a blind hole could not be expected to have the same life as a fairly large carbide-tipped reamer. Definite information on tool life is not yet available. However, it is expected that a complete schedule will be worked out in the near future whereby each tool will be changed at certain stated intervals.

A broken tool which remains in the hole would prevent the following tool from completing its stroke and would thus cause the machine to refuse to start the next cycle. In the case of a chipped tool such as a spot facer, there is no automatic detection mechanism, and the fault might not be discovered until the part was removed from the machine. There is a strong probability, however, that the squeal made by such a tool would lead to its early discovery.

5 What is the length of time the machine must be shut down each day for tool maintenance?

This will vary according to the amount of tool change; no information is as yet available.

Additional questions were asked which were either irrelevant or cannot be answered because of military secrecy.

H. E. Linsley.[7]

[7] Public Relations, Wright Aeronautical Corporation, Paterson, N. J.

A.S.M.E. BOILER CODE

Interpretations

The Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Anyone desiring information on the application of the Code is requested to communicate with the Committee Secretary, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are then sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and is passed upon at a regular meeting of the Committee.

This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval after which it is issued to the inquirer and also published in Mechanical Engineering.

Following is a record of the interpretations of this Committee formulated at the meeting of January 16, 1942, subsequently approved by the Council of The American Society of Mechanical Engineers. Case No. 958 was approved by the Executive Committee and action confirmed by the Boiler Code Committee at its meeting on February 20, 1942.

Case No. 955

(Interpretation of Par. P-108)

Inquiry: Was it the intent that Par. P-108(*c*)(3) be applied to the attachment of valves to piping?

Reply: It is the opinion of the Committee that in the case of welded piping and tubing, the width of the circumferential band shall be at least three times the width of the widest part of the welding groove, but in no case less than twice the width of the weld reinforcement.

Case No. 956

(Interpretation of Specification S-36)

Inquiry: As a variety of copper silicon alloys not covered by present Specification S-36 have come into use, may not such alloys as are included in A.S.T.M. Specifications B96–41T be employed in the construction of Code vessels?

Reply: It is proposed to revise Specification S-36 to correspond with A.S.T.M. Specifications B96–41T. Until such revision has been adopted, materials complying with that specification may be considered as meeting the intent of the Code and be used in the construction of Code vessels.

Case No. 957

(Interpretation of Par. H-29)

Inquiry: Under present emergency conditions, it is very difficult, if not impossible, to secure washout plugs with nonferrous threads for use in steel heating boilers. In view of these conditions, may washout plugs with ferrous threads be substituted?

Reply: It is the opinion of the Committee that washout plugs with ferrous threads may be used in steel heating boilers until this Case is annuled or until such time as plugs with nonferrous threads are again readily obtainable for this service.

Case No. 958

(Interpretation of Specification S-18)

Inquiry: The Code states that welded and seamless open-hearth steel tubes, grades A and B, complying with A.S.T.M Specifications A106-39, will be acceptable as complying with Specification S-18. Will tubes complying with A.S.T.M. Specifications A106-41 be acceptable as complying with Specification S-18?

Reply: It is the opinion of the Committee that welded and seamless open-hearth steel tubes, grades A and B, complying with A.S.T.M. Specifications A106-41, will be acceptable as complying with Specification S-18.

Revisions and Addenda to Boiler Construction Code

It is the policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision of the rules and its codes. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the code, to be included later in the proper place in the code.

The following proposed revisions have been approved for publication as proposed addenda to the code. They are published below with the corresponding paragraph numbers to identify their locations in the various sections of the code, and are submitted for criticism and approval from anyone interested therein. It is to be noted that a proposed revision of the code should not be considered final until formally adopted by the Council of the Society and issued as pink-colored addenda sheets. Added words are printed in small capitals; words to be deleted are enclosed in brackets [ ]. Communications should be addressed to Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be presented to the Committee for consideration.

Table P-2. Delete from the heading of the table reference to Specifications S-48 and S-49; Add to Note 4, reference to Specifications S-52;

Revise the reference to Specifications S-17, S-32, and S-40 in the heading of the table to read: "S-17, S-32 grades A and B, and S-40."

PARS. P-103(a) AND U-71(a). Include reference to Specifications S-5, S-7, S-16, and S-62.

PAR. P-108(c). Add the following as Par. P-108(c)(4):

(4) In the case of welded piping and tubing, the width of the circumferential band shall be at least three times the width of the widest part of the welding groove, but in no case less than twice the width of the weld reinforcement.

PAR. A-47. Delete.

PAR. A-53. Delete last sentence.

PAR. A-57. Revise as follows:

A-57 When the maximum allowable working pressure exceeds 125 lb per sq in., the blowoff pipe shall be AT LEAST extra heavy from the boiler to the valve or valves, and shall run full size without reducers or bushings (See Pars. P-25 and P-310).

All fittings between the boiler and valve shall be steel or AT LEAST extra heavy fittings of bronze, brass, malleable iron, or cast iron, ALL OF WHICH SHALL BE SUITABLE FOR THE PRESSURE AND TEMPERATURE. In case of replacement of pipe or fittings in the blowoff lines, as specified in this paragraph, they shall be installed in accordance with the rules for new installations (See Pars. P-307 to P-313).

PAR. A-58. Revise the first sentence to read:

When the maximum allowable working pressure exceeds 125 lb per sq in., each bottom blowoff pipe shall be fitted with AT LEAST [an extra-heavy] A 250 LB STANDARD valve or cock.

PAR. U-6(a). Revise to read:

(a) For vessels in which the pressure is not generated but is derived from an outside source, each safety valve shall be so connected to the vessel, vessels, or system which it protects, as to prevent a rise in pressure [beyond] WHILE THE SAFETY VALVES ARE BLOWING OFF MORE THAN 10 PER CENT ABOVE the maximum allowable working pressure (see Par. U-2) in any vessel protected by the safety valve.

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

"True Steel"

REVIEWED BY ALLAN R. CULLIMORE[1]

TRUE STEEL. By Christy Borth. The Bobbs-Merrill Co., Indianapolis, Ind., 1941. Cloth, 6 × 8½ in., 319 pp., illus., $3.

YEARS ago someone gave me a definition which seemed to me so sound that I found occasion to use it many times. It might apply definitely to "True Steel" by Christy Borth—"Art is truth intensified."

Perhaps this "intensification" is what makes the book readable, makes some of the phrases stick, and creates an impression which is wholly desirable.

Frankly stated, the moving spirit of the book is "steel without strife," and facts and incidents and anecdotes are gathered together to substantiate the point of view that steel can be made without strife and that the pioneers of the American Rolling Mill Company were keenly sensitive to some of the human problems that have to do with management and personnel—problems which then were new but which now have assumed an importance which in many cases constitutes the difference between success and failure in our industrial world.

The value of this particular motif is tremendously enhanced by the fact that the biography is written while many of the characters still live, where incidents and anecdotes are easy to secure, and where not only the philosophies of the characters may be judged by circumstantial evidence but where they can in the flesh transmit to the biographer at firsthand their personal contribution.

The reviewer feels strongly that American industry needs many such biographies. He also feels very strongly that such biographies should be written when firsthand material is available, and the very best firsthand material lies in character and personality as it impinges upon the biographer.

Beyond the more or less abstract motif of "steel without strife" there emerges in this book—and there should emerge in every true biography—the philosophy of the hero, and he should be a hero, George M. Verity. It is a philosophy which not only may be tremendously valuable in the steel business, but it is a philosophy which has some broader bearing and which every reader—whether he is in the steel business or not—can take home to himself as something worth while.

Perhaps in a biography well written there shines through, in spite of the abstract motif, the larger characteristics of the hero. If this reviewer interprets the book aright, the primary characteristics which lie behind "True Steel" and "steel without strife" are those two general characteristics which were possessed by Mr. Verity in such a considerable degree—courage and sincerity.

It might be a fair question to ask who of our great leaders were without them, and it might be just as fair a question to ask who of our great leaders should exist without them. And so the story of Armco not only fits into but makes more understandable the great American picture, particularly to those young Americans who are beginning to learn something of the America of the future. Its hero points the way to a rather simple, but perhaps the most effective, philosophy which has characterized our great leaders in industry as well as in politics. "I try to be honest with others and myself, and I am not afraid."

[1] President, Newark College of Engineering, Newark, N. J. Mem. A.S.M.E.

Wood

WOOD TECHNOLOGY. By Harry D. Tiemann. Pitman Publishing Corp., New York, N. Y., 1942. Cloth, 6 × 9 in., 326 pp., 129 illus., diagrams, tables, etc., $3.50.

REVIEWED BY THOMAS D. PERRY[2]

TECHNOLOGY, as a word, has been sadly abused by many writers, but in this case it is aptly applied in its broadest meaning. There has been a serious lack of a concise and comprehensive book on the natural characteristics, engineering properties, and practical uses of wood. Professor Tiemann has a broad background of experience and has brought together in one modest volume a most succinct compilation of information about wood and its application to industry.

The book describes what wood is, the life of the tree, the structure of the wood cell, and outlines its behavior under varied conditions of service. The chemical utilization of wood, including paper

[2] Resinous Products, & Chemical Co. Philadelphia, Pa. Mem. A.S.M.E.

and pulp, is well described. The phenomenon of wood shrinkage and swelling is discussed, together with their relation to the problems of natural and mechanical seasoning. The effect of heat on wood strength is adequately explained and high-frequency electric methods of drying wood and curing resin adhesives are outlined. Wood density and impregnation problems come in for their share of attention. The menace of insect pests and fungus growths is well covered in the text. And last, but not least, is a valuable compilation of the mechanical properties of wood and a reasonable method of identifying the various species that grow in the United States. Adequate references are given at the end of each chapter, and useful appendices are included on pertinent phases of wood utilization.

The book stands out as an unusual contribution to technical literature in that it skillfully covers a large subject in an interesting and effective manner, as well as in compact form. It will prove to be an essential volume in the library of any engineer who uses wood and wood products of any kind.

Shop Management

SHOP MANAGEMENT FOR THE SHOP SUPERVISOR. By Ralph Currier Davis. Harper & Bros., New York, N. Y., 1941. Cloth, $5^1/_4 \times 8$ in., 333 pp., 43 figs., \$2.

REVIEWED BY C. W. LYTLE[3]

THIS book should be judged in the light of its intended use, that is, as a general explanation of management philosophy for supervisors and foremen. For such use we find the book readable and sensible. The treatment is not restricted to any kind or scale of industry. It is wisely kept in terms of principles which may be modified to suit circumstances. By explaining the requirements of varying circumstances it is made clear how and why the same general principles can be varied to suit each main type and size of application.

Early in the book comes recognition of variation in foremanship jobs. The author's analysis of several different kinds of foremanship should be helpful in any critical study of foremanship; and this is particularly important right now as a prerequisite to foreman training.

Distinction between the natures of line and staff functions is clean-cut and may well be read thoughtfully by management because there is a surprising amount of misconception current in this important matter.

Management terminology is straightened out by many definitions, which we think on the whole are sound. We wish however that they might have been set apart to give them emphasis. In fact the book seems to have been hurriedly written, that is, given too little editing and very little documentation.

Paragraphs and their headings are not well balanced. The latter vary in frequency from eight pages to a few lines. Perhaps this is not a serious fault, but most engineering readers like at least one heading per page.

Although there are several practical formulas given, for instance, one for lot sizes, in the main the book is not technical. Techniques, like the Gantt charts, are merely mentioned, and the reader is referred to the best literature on the subject.

The author's insistence that planning should precede organization suggests that these functions are not only sequential but recurring for all new objectives. His chart of basic factors is almost universal in its application and hence valuable anywhere.

There is a 45-page chapter on the control of job-shop production. This should be of value as this type of work could use more scientific management; and not much that is definite has been published.

The chapter on Motion and Time Study, although plenty long, seems too general for anyone contemplating work in that field. It would, however, be clarifying to a supervisor.

Job evaluation, a subject of considerable interest now, is only mentioned; wage incentives are given little more attention. The morale problem, however, is touched upon repeatedly.

It is evident that the author's interest and experience is in the fields of organization and control. These fields are well treated, rather more definite than usual. For instance, the relation of each management function to other functions is shown by an incomplete chart. These suffer somewhat by being incomplete and separated, also from too-small type; but they serve the purpose of illustrating best practice in organization and are superior to many earlier attempts in this direction. In fact there is more definiteness than might be expected in so short and general a treatment of an enormous subject.

Where a nontechnical and readable book is needed to help supervisors in these matters, this book is good, and for such use we heartily endorse it.

[3] Associate Professor of Administrative Engineering, New York University, New York, N. Y. Mem. A.S.M.E.

Books Received in Library

AIRCRAFT TORCH WELDING. By C. von Borchers and A. Ciffrin. Pitman Publishing Corp., New York and Chicago, 1941. Cloth, $5 \times 8^1/_2$ in., 157 pp., illus., diagrams, charts, tables, \$1.50. This book outlines a training course for aircraft welders based on well-established principles. It deals only with gas welding. Topics treated include equipment, the use of gases, torch and flames, welding technique, jigs and fixtures, inspection methods and repair welding. Review questions accompany each chapter.

AIRPLANE DESIGN. By K. D. Wood. Sixth edition, published by the author at Purdue University, Lafayette, Ind., Nov., 1941. Distributed by the Cornell Co-op Society, Ithaca, N. Y., paged in sections. Paper, 9×11 in., illus., diagrams, charts, tables, \$4. Practical design procedure covering airplane layout and stress calculations is presented in this textbook. Particular emphasis is laid on the economics of airplane design, and many photographs and diagrams accompany the descriptive material. A large appendix furnishes most of the data necessary for a student to carry a design project through its preliminary stages.

A.S.T.M. STANDARDS ON RUBBER PRODUCTS, prepared by A.S.T.M. Committee D-11 on Rubber Products. Methods of Testing, Specifications. American Society for Testing Materials, Philadelphia, Pa., 1941. Paper, 6×9 in., 280 pp., illus., diagrams, charts, tables, \$1.75. This annual publication gives in their latest approved form the specifications and methods of test adopted by the Society. Among them are several new standards. There are also numerous revisions of earlier ones. There is a useful bibliography on the properties and testing of rubber.

FLIGHT, Aircraft Engines, a General Survey of Fundamentals of Aviation. By R. F. Kuns. American Technical Society, Chicago, Ill., 1942. Paged in sections. Cloth, $6 \times 9\ ^1/_2$ in., illus., diagrams, charts, tables, \$3.25. A discussion of elementary engines precedes chapters on light plane engines and radial aircraft engines. Other chapters provide practical information on engine fuels and fuel systems, electrical equipment, lubrication, and valve and ignition timing. There are many photographs and cross-sectional diagrams, and a section of review questions with answers is included.

FLUID MECHANICS AND STATISTICAL METHODS IN ENGINEERING. (University of Pennsylvania Bicentennial Conference.) By H. L. Dryden, T. von Kármán, and others. University of Pennsylvania Press, Philadelphia, 1941. Cloth, $6 \times 9^1/_2$ in., 146 pp., illus., diagrams, charts, tables, \$1.75. The eight papers by recognized authorities contained in this work are divided into two groups. Four of them deal with turbulence and related topics in the field of fluid mechanics. The other four, grouped under the heading of statistical methods in engineering, range from the contribution of statistics to purchasing specifications to the application of the statistical method in legislation.

HANDBOOK OF SLEEVE BEARINGS. By A. B. Willi. Federal-Mogul Corporation, Detroit, Mich., 1941. Cloth, $6 \times 9^1/_2$ in., illus., diagrams, charts, tables (available only to those directly concerned with sleeve-bearing installations). This practical guide for the engineer, designer, and draftsman deals with the selection, design, and applicaion of sleeve bearings.

It discusses, for example, the effect of design, materials, and manufacturing methods upon sleeve-bearing efficiency and other special topics of major importance in setting up bearing specifications. There is a large reference section listing many sizes and types of bearings for which major manufacturing tools are now available.

HIGHER MATHEMATICS FOR ENGINEERS AND PHYSICISTS. By I. S. Sokolnikoff and E. S. Sokolnikoff. Second edition. McGraw-Hill Book Co., Inc., New York, N. Y., and London, England, 1941. Cloth, 6 × 9$^1/_2$ in., 587 pp., diagrams, charts, tables, \$4.50. The purpose of this book is to give students of engineering and other applied sciences a bird's-eye view of those mathematical topics beyond the elementary calculus which are indispensable in the study of physical sciences. Underlying principles are emphasized, rather than direct application to specific problems, so as to provide an introduction to advanced mathematical treatises. The new edition has been considerably revised and enlarged.

INDUSTRIAL ACCIDENT PREVENTION, a Scientific Approach. By H. W. Heinrich. Second edition. McGraw-Hill Book Co., Inc., New York, N. Y., and London, England, 1941. Cloth, 5$^1/_2$ × 8$^1/_2$ in., 448 pp., illus., diagrams, charts, tables, \$3. The essential principles and basic philosophy of accident prevention are presented in the first two chapters. The next three are devoted to an explanation of the practical application of these principles in industry. Further development of various phases of the subject and specific illustrative examples are found in succeeding chapters. Historical and statistical data are appended.

INDUSTRIAL INSTRUMENTS FOR MEASUREMENT AND CONTROL. (Chemical Engineering Series.) By T. J. Rhodes. McGraw-Hill Book Co., Inc., New York, N. Y., and London, England, 1941. Cloth, 6 × 9 in., 573 pp., diagrams, charts, tables, \$6. This new text is designed to provide a theoretical and practical treatment of the measurement and control of the four fundamental physical factors encountered in industrial processing and manufacturing, temperature, pressure, fluid flow, and liquid level. Automatically controlled continuous processes are thoroughly analyzed, and practical rules are established for the design and maintenance of controlling instruments.

INTRODUCTION TO PHYSICAL STATISTICS. By R. B. Lindsay. John Wiley & Sons, Inc., New York, N. Y.; Chapman & Hall, London, England, 1941. Cloth, 6 × 9$^1/_2$ in., 306 pp., diagrams, charts, tables, \$3.75. This work is intended for the graduate student who wishes a thorough but not too lengthy introduction to the method of statistical physics. It calls for a background of theoretical physics. It presents a survey of the various ways in which statistical reasoning has been used in physics, from the classical applications to fluctuation phenomena, kinetic theory and statistical mechanics to the contemporary quantum mechanical statistics. Emphasis has been laid on methodology and numerous illustrative problems are included.

MACHINE SHOP, Theory and Practice. By A. M. Wagener and H. O. Arthur. D. Van Nostrand Co., Inc., New York, N. Y., 1941. Cloth and paper, 8$^1/_2$ × 11 in., 306 pp., illus., diagrams, charts, tables, cloth, \$2.28, paper, \$1.60. The introductory and closing chapters of this textbook for beginners and apprentices in the machine trades describe, respectively, the commonly used precision and semiprecision tools found in the shop, and the uses of the so-called bench tools and small hand tools. The construction and operation of the various machines, from shapers to grinders, are dealt with in between in a practical order and manner. Safety suggestions, review questions, and many illustrations are included.

MACRAE'S BLUE BOOK, 49th Annual Edition, 1941–1942. MacRae's Blue Book Co., Chicago, Ill., and New York, N. Y., 1941. Cloth, 8 × 11 in., 3728 pp., illus., \$15. The new edition of this well-known and useful directory follows the plan of preceding ones. It includes an alphabetical list of manufacturers, producers, and wholesalers, with the addresses of branch offices; a minutely classified list of products, with an extensive index; a list of towns of one thousand or more population, with their trade facilities and railroad connections; and a list of trade names.

PHOTOMICROGRAPHY. By R. M. Allen. D. Van Nostrand Co., Inc., New York, N. Y., 1941. Cloth, 6 × 9$^1/_2$ in., 365 pp., illus., diagrams, charts, tables, \$5.50. The process of photographing minute objects through a microscope is comprehensively covered. Essential information concerning microscopic technique is provided for those unfamiliar with such work, although the emphasis is upon photographic equipment and methods, which are described in detail. Excellent examples of various kinds of photomicrography are included, with explanatory paragraphs.

PIPING FLEXIBILITY AND STRESSES. By S. D. Vinieratos and D. R. Zeno. Cornell Maritime Press, New York, N. Y., 1941. Paper, 7$^1/_2$ × 10 in., 85 pp., diagrams, charts, tables, \$3. The graphoanalytical method of determining flexibility and stress from an examination of bending-moment diagrams is presented in this book for the design of piping systems, particularly steam piping in marine service. The fundamentals of the method are first briefly described, and its application is then explained, working from simple cases to problems with pipes intersecting in space.

PLASTICS MOLD DESIGNING. By G. B. Thayer. American Industrial Publishers, Cleveland, Ohio, 1941. Cloth, 6 × 9$^1/_2$ in., 64 pp., illus., diagrams, tables, \$2.50. The fundamentals of plastics mold design are discussed and applied to representative types of compression and injection molds. Some space is devoted to fixtures, mold sinking methods are described, and product design is discussed in relation to mold building methods.

PRACTICAL MATHEMATICS FOR SHIPFITTERS AND OTHER SHIPYARD WORKERS. By L. Q. Moss. Pitman Publishing Corporation, New York, N. Y., and Chicago, Ill., 1941. Cloth, 5 × 8$^1/_2$ in., 108 pp., diagrams, charts, tables, \$1.50. This simple presentation of mathematics is intended for use by organizations participating in the current program for training shipyard workers. Every problem illustrates an application of a mathematical process to a real trade situation, and the text has been thoroughly tested in the classroom.

REFERENCE LIBRARY OF THE WELDING RESEARCH COUNCIL, Section I, Classified Library Catalogue, June, 1941. Published by Institute of Welding, London, S.W.1, England. Paper, 5$^1/_2$ × 8$^1/_2$ in., 136 pp., 2s. The major part of this publication is devoted to a catalogue of the reference library of the Welding Research Council, containing both author and subject entries in one alphabetical list.

TECHNICAL REPORT WRITING. (Chemical Engineering Series.) By F. H. Rhodes. McGraw-Hill Book Co., Inc., New York, N. Y., and London, England, 1941. Cloth, 6 × 9$^1/_2$ in., 125 pp., charts, tables, \$1.50. This guide to report writing is based on long experience in teaching the art to engineering students and can be recommended as an excellent one. By confining himself to reports and omitting the material on other technical writing usually found in texts on the subject, the author has covered the subject thoroughly and practically in a small book.

TRAINS IN TRANSITION. By L. Beebe. D. Appleton-Century Co., New York, N. Y., and London, England, 1941. Cloth, 8 × 11$^1/_2$ in., 210 pp., illus., tables, \$5. The third of Mr. Beebe's books on American railroading offers the same attractive combination of readable text and excellent photographs that its predecessors displayed. In this volume, the author is concerned with the changes in practice and equipment which have taken place in recent years, especially the effects of the Diesel-electric locomotive, lightweight cars, and air-flow design.

UNIVERSITY PHYSICS, Part 3, LIGHT. By F. C. Champion. Interscience Publishers, New York, N. Y., Blackie & Son, London, England, and Glasgow, Scotland, 1941. Cloth, 6 × 9 in., 172 pp., diagrams, charts, tables, \$1.50. One of a group of books on the several major divisions of physics, this particular volume covers the subject of light for intermediate students who have previously studied the elements of physics. The text is supplemented by numerous clear and helpful diagrams, and exercises and problems are supplied for review.

WATER PURIFICATION FOR PLANT OPERATORS. By G. D. Norcom and K. W. Brown. McGraw-Hill Book Co., New York, N. Y., and London, England, 1942. Cloth, 6 × 9 in., 180 pp., illus., diagrams, charts, tables, \$2.50. This is a comprehensive instruction book for filter-plant operators, in which theory and practice are discussed in an elementary way for those without technical education. The structures and equipment used in water purification are described, and operating methods given in full.

WAVES, a Mathematical Account of the Common Types of Wave Motion. By C. A. Coulson. Oliver & Boyd, London, England, and Edinburgh, Scotland, 1941. Cloth, 5 × 7$^1/_2$ in., 156 pp., diagrams, charts, tables, 5s. The subject of waves is usually treated in separate branches of applied mathematics. In this book, as many different kinds of wave motion as possible are discussed as one whole, in an elementary way. Starting from the standard equation of wave motion, the author investigates waves on strings, in membranes, bars, and springs, and in liquids, sound waves, and electric waves; concluding with a chapter on some general properties of waves.

Library Services

ENGINEERING Societies Library books may be borrowed by mail by A.S.M.E. members for a small handling charge. The Library also prepares bibliographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Harrison W. Craver, Director, Engineering Societies Library, 29 West 39th St., New York, N. Y.

A.S.M.E. NEWS

And Notes on Other Engineering Activities

Cleveland—City of Varied Interests and Industries—Invites You to Attend A.S.M.E. Semi-Annual Meeting

June 8 to 10, 1942

THE 1942 Semi-Annual Meeting of The American Society of Mechanical Engineers will be held in Cleveland, Ohio, June 8–10. This announcement is made only after careful consideration, by the Executive Committee of the Council of the Society and the Standing Committees on Meetings and Program and on Professional Divisions, of all phases of the desirability of conducting engineering meetings during wartime. It has been decided that continuing the regular meetings of the A.S.M.E. during these times will be a real contribution to the production of war material because of the opportunity thus afforded to those in charge of manufacture to meet and exchange ideas.

Regular Semi-Annual Business Meeting

The Society will hold the regular semi-annual business meeting during the convention. There will also be a meeting of the Council, and the Nominating Committee will hold open sessions to give the members an opportunity to appear and to present their views on qualifications of candidates for office in the Society for 1943.

Program Pointed Toward Government Requirements

Obviously the program will be pointed toward the discussion of papers that have a direct bearing upon the requirements of the Government at this time. Even at this early date sessions have been requested by the Aviation, Railroad, Metals Engineering, Management, and Materials Handling Divisions, and the Committee on Education and Training for the Industries. In addition it is expected that there will be a complete discussion of gages and gaging problems and probably an exhibit of available instruments of this character.

The Production Engineering Division has plans for two sessions at the Meeting, one on grinding and the other on flame hardening.

HOTEL STATLER, CLEVELAND, HEADQUARTERS FOR A.S.M.E. SEMI-ANNUAL MEETING, JUNE 8–10, 1942

Representatives from Linde Products and users will present the experiences with this process.

Warner Seely to Head Local Committee

The Cleveland local committee, headed by Warner Seely, secretary of the Warner & Swasey Company, is actively at work planning the arrangements for the plant visits and the entertainment of the members.

It is interesting to note that in the program of the corresponding meeting of the Society held in Cleveland in 1924 two of the papers presented were on aerial bombing and the role of the engineer in industrial-mobilization planning.

Headquarters at Statler

Headquarters for the meeting will be the Hotel Statler, strategically located in the heart of the "Convention City of America," to receive visitors from all quarters. For those arriving by air the Cleveland Municipal Airport is readily accessible by regularly scheduled service to the headquarters hotel.

Cleveland is the home of Western Reserve University, Case School of Applied Science, the Cleveland Clinic, the Cleveland Art Museum, Western Reserve Historical Society, and Severance Hall, the permanent auditorium for the Cleveland Symphony Orchestra—a city of culture and education and a science center.

It is hoped to include in the May issue of MECHANICAL ENGINEERING the technical program of the Meeting.

Courtesy Cleveland Convention Bureau

CLEVELAND'S TERMINAL TOWER GROUP OVERLOOKING THE PUBLIC SQUARE

(Observation platform on forty-second floor provides a sweeping view of Northern Ohio.)

Actions of A.S.M.E. Executive Committee

at Meeting in Society Headquarters on February 18

A MEETING of the Executive Committee of the Council of the The American Society of Mechanical Engineers was held in the rooms of the Society on February 18. After luncheon the committee met, on special invitation, with members of the Committee on Professional Divisions. At both sessions James W. Parker, president A.S.M.E., presided, and there were present Clarke Freeman, vice-chairman; Clair B. Peck and G. E. Hulse, of the Committee; K. W. Jappe (Finance), W. A. Carter (Professional Divisions), J. N. Landis (Local Sections), C. E. Davies, secretary; and Ernest Hartford, executive assistant secretary. At the afternoon session G. B. Karelitz and W. M. Sheehan, of the Standing Committee on Professional Divisions, were also present.

The following actions were of general interest.

Branch at Queen's University

On recommendation of the Committee on Relations with the Colleges, establishment of an A.S.M.E. student branch at Queen's University, Kingston, Ontario, Canada, was authorized.

Professional Divisions

The policies of the Committee on Professional Divisions were discussed at the afternoon session. Satisfactory progress was reported in the Aviation Division and appreciation was expressed for the additional appropriation for division activities.

Appointments

The following appointments were reported for the record:

Committee on Engineers' Civic Responsibilities, Gano Dunn; Special Research Committees, Condenser Tubes, Fluid Meters, E. S. Bunn and I. O. Miner; P.T.C. Committee No. 20 on Speed, Temperature, and Pressure Responsive Governors, Raymond Sheppard; Joint A.I.E.E.-A.S.M.E. Committee on Specifications for Prime Mover Speed Governing, J. R. Hagemann and Raymond Sheppard; Sectional Committee on Safety Code for Prevention of Dust Explosions, Walter S. Rearick, alternate to R. M. Ferry; Tellers on Election of Vice-President, E. B. Ricketts and C. B. Peck; National Management Council, A. I. Peterson (replacing L. P. Alford, 1943); Gantt Medal Board of Award, A. I. Peterson (1943 unexpired term of L. P. Alford); Washington Award Presentation to W. L. Abbott, Chicago, February 26, Alex D. Bailey; American Academy of Political and Social Science, annual meeting, Philadelphia, Pa., April 10–11, J. Harland Billings, J. Edwin Fulweiler, and J. Stanley Morehouse.

A.S.M.E. Calendar

of Coming Meetings

June 8–11, 1942
Semi-Annual Meeting
Cleveland, Ohio

June 17–19, 1942
Oil and Gas Power Division
Peoria, Ill.

June 19–20, 1942
Applied Mechanics Division
Massachusetts Institute of Technology
Cambridge, Mass.

October 12–14, 1942
Fall Meeting
Rochester, N. Y.

Nov. 30–Dec. 4, 1942
Annual Meeting
New York, N. Y.

(*For coming meetings of other organizations see page 34 of the advertising section of this issue*)

Midwest Power Conference to Meet at Chicago April 9 and 10

AS announced in the March issue, page 243, the Midwest Power Conference will be held in Chicago, April 9 and 10, with headquarters at the Palmer House. Additions to the list of papers and speakers announced last month include the addresses to be delivered at the luncheon and dinner on April 9. Otto K. Jelinek, chief of techniques, Chicago metropolitan area, will speak at the joint luncheon with the Chicago Section, A.S.M.E., at which C. C. Austin, chairman of the Section, will preside. Mr. Jelinek will speak on "Problems of Blackouts and Bombings."

Willard Chevalier, vice-president, McGraw-Hill Publishing Company, and publisher of *Business Week* will address the "All-Engineers" dinner on Thursday evening on the subject "Business Looks at the War."

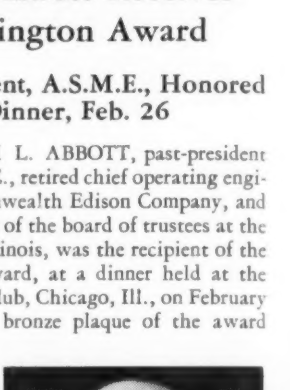
Outline on Administrative Organization Available

AT THE 1941 Annual Meeting of The American Society of Mechanical Engineers the Management Division sponsored a panel discussion of the question, "What is top management actually doing about the supervisory problem?" Although the discussion was oral and no stenographic report of it was made, F. M. Gilbreth, junior adviser of the Division, prepared a topical outline sufficiently complete to be useful to members interested in the subject. The outline has been mimeographed and copies are available on request. Address the Secretary, The American Society of Mechanical Engineers, 29 W. 39th Street, New York, N. Y.

W. L. Abbott Receives Washington Award

Past-President, A.S.M.E., Honored at Dinner, Feb. 26

WILLIAM L. ABBOTT, past-president A.S.M.E., retired chief operating engineer of Commonwealth Edison Company, and former president of the board of trustees at the University of Illinois, was the recipient of the Washington Award, at a dinner held at the Union League Club, Chicago, Ill., on February 26, 1942. The bronze plaque of the award bears the inscription: "For advancing the standards of the engineering profession; for services to higher education; for aiding combustion research."



W. L. ABBOTT

Founded in 1916 by John W. Alvord of Chicago, the Washington award is conferred by a commission representing the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, American Institute of Electrical Engineers, and Western Society of Engineers for accomplishments promoting the happiness, comfort, and well-being of humanity. Previous recipients include Herbert Hoover, Orville Wright, Michael Pupin, Bion J. Arnold, Ralph Modjeski, Charles F. Kettering, and Ralph Budd.

Arthur C. Willard, Member A.S.M.E., president of the University of Illinois, was the principal speaker at the testimonial dinner. L. R. Howson, member A.S.M.E., chairman of the Washington Award Commission, reviewed the history of the citation and F. H. Lane, member A.S.M.E., president of the Western Society of Engineers, presented the plaque.

A.S.M.E. Members on Duty in England Extended Courtesies by I.M.E.

A LETTER from J. E. Montgomery, secretary of The Institution of Mechanical Engineers, London, announces that the Council of the Institution will be happy to make contact with members of The American Society of Mechanical Engineers on duty in England with the U. S. Army, either at headquarters, Storey's Gate, St. James Park, or at any branches, where they will be received as guests at meetings and extended other courtesies and assistance.

Allocating Research Projects Referred to A.S.M.E. Research Committee

Procedure Approved by Committee

A PROCEDURE by means of which the Research Committee of The American Society of Mechanical Engineers will allocate research projects and problems referred to it was approved by the Committee on November 30, 1941.

In an effort to co-operate closely with the professional divisions of the Society, the Committee asked and received the permission of the Council to set up a group of research secretaries, to be made up of official representatives of each of the professional divisions. The plan of co-operation and the functions of these research secretaries were explained in a report of the Research Committee that appeared in the March, 1941, issue of MECHANICAL ENGINEERING. In the same issue announcement was made of the research secretaries that had been appointed up to that time.

First Year Brought Many Problems

One of the functions of these research secretaries is to suggest to the Research Committee projects and problems which, in the opinion of the professional division, should be referred to the Committee. During the first year of operation of the plan which involved the co-operation of the research secretaries, a number of problems and projects were referred to the Research Committee. A study of these suggestions indicated that clarification of the procedure of the Research Committee was needed. It became evident that not all of the problems and projects suggested could properly be undertaken by the special research committees which it is the practice of the Main Research Committee to set up for the guidance of specific researches. Some of these suggestions obviously should be passed on to individual manufacturers, or to trade association, or to educational institutions, or to commercial laboratories. The purpose in adopting a procedure of allocation of projects and problems referred to the A.S.M.E. Research Committee is to provide a guide for the use of the Committee in coming to a decision as to what agency should most appropriately consider a specific suggestion.

Procedure Outlined

The procedure approved by the Committee is known as the "Usual Allocation of Research Projects and Problems by the A.S.M.E. Research Committee When Received From the Membership and Industry." An outline of the procedure follows:

1 *To Manufacturers of Equipment and Users of Processes.*
  (*a*) Develop and improve equipment used and manufactured.
  (*b*) Develop and improve processes.

2 *To Associations of Commercial Companies:* Trade associations, such as Association of American Railroads, American Petroleum Institute, Cement Association, Edison Electric Institute, National Coal Association, Bituminous Coal Research, Inc., Anthracite Institute, and the like.
  (*a*) Develop, improve, and standardize equipment, processes, and various subjects in which they are collectively interested.

3 *To Educational Institutions.*
  (*a*) Characteristics of materials, such as:
  Structural strength.
  Fluid properties—flow, viscosity, etc.
  Pressure, temperature, volume relations, etc.
  (*b*) Operating performance of equipment. Operating results from processes, etc.
  (*c*) Methods of chemical analyses. Methods of physical testing.
  (*d*) Numerous other phases of engineering in the form of theses, professional investigation in pure or applied science.

4 *To Endowed or Commercial Laboratories.*
  (*a*) Any of the subjects under items 1, 2, and 3, for individual companies or associations.

5 *To United States Government or State Government Bureaus, or Departments,* such as U. S. Department of Agriculture, U. S. Bureau of Mines, U. S. Bureau of Standards, State Experiment Station, etc.
  (*a*) Various activities of research and development within the laws under which they are authorized.

6 *To The American Society of Mechanical Engineers and other similar societies.*
  (*a*) Research along broad lines for an industry or a group of industries from which general benefit will be derived and which may be too general or too expensive for any one company or association to develop. Also development which cannot or should not be patented, but which should be done collectively for the good of a profession or industry, such as: Boiler feedwater studies, fluid meters, lubrication, thermal properties of steam, effect of temperature on properties of metals, furnace performance factors, etc.
  (*b*) Co-ordination and agreement on methods for testing equipment, etc., such as power test codes, boiler code.
  Such projects may be jointly supported by manufacturers, associations, users, etc.

New Standard Symbols for Hydraulics and Mechanics Approved

NEW American standards for letter symbols for Hydraulics (Z10.2–1942), a revision of the standard approved and published in 1929, and for Mechanics of Solid Bodies (Z10.3–1942), a revision of the standard approved and published in 1932, were approved by the American Standards Association on Jan. 19, 1942. Copies of these new standards are now available for distribution and may be ordered from the Publication Sales Department, A.S.M.E., 29 West 39th St., New York, N. Y.

Engineers' Defense Board Recommends Changes in Federal Specification

SPECIFIC recommendations for conservation of steel in a wide range of uses have been made to the War Production Board by the Engineers' Defense Board, technical group sponsored by the American Society of Civil Engineers, The American Society of Mechanical Engineers, the American Institute of Mining and Metallurgical Engineers, the American Institute of Electrical Engineers, the Society of Automotive Engineers, and the American Institute of Chemical Engineers.

In a letter addressed to H. LeRoy Whitney, chief, technical and engineering section, Iron and Steel Branch, W.P.B., the Engineers' Defense Board suggests changes in Federal specifications to encourage greater salvage activities, the issuance of special appeals for increased salvage of steel regardless of profit possibilities, and adoption by municipalities and politial subdivisions of an emergency manual to liberalize types of construction materials, working stresses, etc., to effect material reductions in quantities of steel used.

Recommending immediate preparation of manual agreed upon by all commercial, technical, and military interests, the Board urges that its provision be made applicable to all structures needed for the national emergency, bearing in mind that many will be of a temporary nature.

It urges also that steel may well be conserved in bridge construction by recognizing, as standard for the design of railway bridges, the 1941 edition of the Specifications for Steel Railway Bridges of the American Railway Engineering Association.

Idle Machine Tools Are Requested by W.P.B.

OWNERS of idle machine tools have been requested by George C. Brainard, chief of the tools branch, War Production Board, to make them available for sale so they can be placed in plants engaged in war production.

It is urged that full information regarding such idle tools be forwarded to the Available Used Tools Section of the War Production Board where it can be incorporated in reference files for operators of war production plants. Recent recording of tools in the possession of used-machine-tool dealers are said to have resulted in the listing of approximately 40,000 idle machines. Many of these have found their way into war production and every effort is being made to keep the list up to date by adding more tools to it.

It is estimated that if owners of idle machines co-operate fully in listing their tools, approximately 50,000 pieces of equipment may be made available for sale to war-material producers.

Shop foremen are asked to search their plants for "forgotten" machinery. Plant operators having several machine tools of the same type are urged to consider the possibility of doing the work on fewer pieces of equipment and releasing the others for war work.

Courtesy Cleveland Convention Bureau

NIGHT SCENE ALONG THE CUYAHOGA RIVER IN THE STEEL-MILL DISTRICT OF CLEVELAND

(A.S.M.E. Semi-Annual Meeting at Cleveland, Ohio, June 8–10. See page 319.)

A.S.M.E. Sections Urged to Discuss Conservation and Reclamation

Management Division Offers Suggestions

FOLLOWING up the interest shown in the session on conservation and reclamation of materials at the 1941 A.S.M.E. Annual Meeting, which was reported on pages 25 to 32 of the January issue of MECHANICAL ENGINEERING, the A.S.M.E. Management Division has sent a memorandum, "How Your Section Can Aid War Production," to all of the A.S.M.E. local sections.

With the memorandum were sent reprints of the pages from MECHANICAL ENGINEERING referred to and of three articles from *Factory Management and Maintenance*, entitled "Erie Gets in the Scrap," "War Metal from Scrap," and "Let's Look at Substitutes."

It was suggested in the memorandum that each section assist in the Society's attempts to conserve materials for the winning of the war. The following suggestions were put forward:

(*a*) Secure from two to four engineers to prepare papers describing specific cases of conservation and reclamation.

(*b*) Secure the services of several experts in design, production, and salvage to participate in answering questions relating to conservation and salvage of materials.

(*c*) Hold a meeting at which the papers are presented and at which the experts, aided by the men who present the papers, will answer the questions of the members of the section relating to conservation and reclamation of materials.

High-Speed Photography in Boiler Furnace Performance Makes Debut at Bridgeport

TO a keenly interested group of 100 members and guests, Dr. W. H. Dargan, of Consolidated-Edison Co., N. Y. C., read a treatise on research in boiler furnace performance, Feb. 25, at the Bridgeport Section. The unusual feature of the meeting was the showing of high-speed films, whose utilization is an innovation at New York Edison, portraying processes going on inside steam boilers. The uses of high-speed film are many. To demonstrate this point, Dr. Dargan showed films of a wrapping machine in operation. Through the ability to slow down motion of high-speed photography, the case of burner and flame action, a viewpoint possible by no other means, is provided. By speeding up action, it is possible to make such phenomena as agitation of stoker bed, and by using infrared photography, certain details, wholly invisible in operation, such as slagging bottoms, are brought to light. Dr. Dargan's talk proved of unusual stimulation, opening as it did endless fields for the application of high-speed photography, not the least of which was that of defense manufacture and consequent speeded production.

Bridges and Aerodynamics Topic at Columbus Meeting

On Feb. 27, 110 members and guests heard Dr. David B. Steinman speak on the subject, "Bridges and Aerodynamics with Special Reference to Tacoma Narrows Bridge." The lecture was of exceptional interest, copiously illustrated by drawings and supplemented with movies. The behavior of the Tacoma Narrows Bridge was pictorialized through the use of models, operated by John Baynton, to demonstrate specific aerodynamics principles.

Smuggling and Fire Fighting at Buffalo Section

The Feb. 19 meeting of Buffalo Section was enlivened by the stirring account of Chungking under fire, presented in words and film by Earl Broderick, who told of smuggling his pictures out of China by wrapping them around his body. Chief Harold R. Becker, the next speaker, in charge of the Buffalo Civilian Defense work in the Buffalo Fire Department, showed two films, one giving an exposition of incendiary bombs, the other, the picture of the individual and community dangers resulting from a false alarm. The third speaker, Edwin L. Ballard, of the Eastern Fire Underwriting Organization, gave a brief description of local fire-fighting facilities available for possible air raids.

Stoker Operation at Detroit

Approximately 125 members and guests attended the March 3 meeting held in the beautiful auditorium of the Engineering Society of Detroit in the new Horace H. Rackham Memorial Building. The meeting was addressed by Otto De Lorenzi of the Combustion Engineering Company of New York City. Mr. De Lorenzi provided an exceedingly interesting, instructive, and entertaining evening by displaying moving pictures showing the burning of coal on stokers. He described in general the operation of underfeed, chain-grate, and spreader type stokers and then illustrated this operation by means of moving pictures taken of the stokers in action. Prior to Mr. De Lorenzi's talk and at the request of the National Office for co-operation with the International Association of Chiefs of Police for more effective traffic-accident prevention, there was an excellent address by inspector Fred W. Jurgens, a representative of the Association and a director of traffic for the City of Detroit Police Department. Inspector Jurgens pointed out the tremendous loss of life, property, and time through traffic accidents, most of which are preventable by proper co-operation of the public, more strict enforcement of the laws, and the education and maintaining of public interest in the official emergency traffic-law-enforcement program.

Magnaflux Testing Methods at Fort Wayne Section

The Feb. 12 meeting of the Fort Wayne Section had as speaker of the evening, Roy O.

Schieble, whose address was entitled "Magnaflux Testing Methods." He described and demonstrated magnaflux testing for surface and subsurface defects in steels and steel parts. The talk was illustrated by slides which also served the purpose of portraying available equipment. Prepared samples were then tested to demonstrate principles discussed.

Honolulu Warned of Gas Attacks by Japanese, at February Meeting

At the Feb. 6 meeting of the Engineering Association of Hawaii, Col. George Unmacht, C.W.S., U. S. Army, spoke on gas attacks and gas protection. He said that Japan has used Lewisite against the Chinese more than 800 times, that Japan and the U. S. were not participants in the treaty which prohibits the use of poison gases in warfare, and that Hawaii must, therefore, prepare for the worst as Japan is not only equipped for such an attack, but has prepared its civilian population against gas.

Minnesota Members Learn About Powder Metallurgy

A joint meeting of the A.I.E.E. and A.S. M.E. was held on Jan. 26 by members of the Minnesota Section. The speaker, R. P. Koehring, metallurgist in charge of research and control, Moraine Products Division, General Motors Corporation, Dayton, Ohio, spoke on "Powder Metallurgy." He defined his subject as the art of producing metal parts from metal powders by means of heat and pressure. The history of powder metallurgy was traced from its beginning in the early nineteenth century, when it was first used for making platinum objects which were difficult to produce otherwise due to the high temperatures involved. Later, tungsten light filaments were produced by this method. In 1920, powder metallurgy came into prominence when it was employed to produce self-lubricating and porous bearing materials. From then on, its rapidly growing numbers of compositions and properties have contributed widely to solving modern engineering problems. Among the newest developments in this art are filter materials, babbitt coating on bronze matrix for steel-backed bearings, and the production of complicated iron parts requiring little or no finishing. The audience was much impressed with the possibilities of this comparatively young technique.

Shell Production Featured at Norwich Section

More than 50 members and guests at the Feb. 24 meeting of the Norwich Section heard Norman H. Schlink, Babcock Printing Press Corp., speak on phases of shell production, from the steel ingot through the final inspection processing. The coating and control were completely described and a series of exhibits shown to illustrate the various steps. Following the talk, members of the new student branch at Connecticut University, were introduced.

Record Audience Sees Film, "Oil for Victory," presented at Philadelphia Section

About 400 members and guests at the Feb. 24 meeting of the Philadelphia Section heard John D. Hill speak on "Oil for Industry and War;" Dr. J. Bennett Hill on "Aviation Motor Gasoline Problems;" and Jack Lane on "High-Speed Diesel Engineering." Following these talks a sound picture "Oil for Victory" was presented through the courtesy of the Standard Oil Co. of Pennsylvania. The evening's topics proved of unusual interest and immediacy.

Inauguration of Discussion Groups at San Francisco

A new plan in section meetings has been inaugurated in the San Francisco Section. The first session of its weekly noon discussion groups was held on Feb. 3, under the joint sponsorship of the Professional Division Committee and the Junior Group. The plan allows two successive meetings for the presentation and discussion of each general topic chosen. The meetings of Feb. 3 and 10 were under the direction of the Management Group, covering the theme of plant protection, involving blackouts, guards, fire, etc., with G. F. Sellers, plant engineer of the Colgate-Palmolive Peet Co., as discussion leader. He presented an excellent analysis of necessary steps to provide adequate protection to industrial plants in the present emergency. Sellers also outlined an organizational setup for a plant to use in handling emergency matters. The purpose of this novel plan in meetings is to foster informal discussion of various phases of engineering activity of special interest to the varied professional groups within the Section itself. Judging by the success of its initial meeting, the plan will flourish.

Texas Engineers View Film on Steel Vessels

Over 100 members and guests at the Feb. 9 meeting of South Texas Section heard R. J. Reed and I. S. Brumagin, Struthers Wills Co., speak on the fabrication of stainless-steel vessels. Following the short talks, a film illustrating the fabrication and heat-treating of pressure vessels of carbon steel as well as the fabrication of stainless-steel vessels and water quenching of same was shown. The motion pictures proved of interest to the entire assemblage.

President Parker Criticizes Critics of Defense Plants in Talk at Utah Section

Many manufacturers now engaged in converting their plants into wartime production have been criticized because their tasks appear to be moving slowly, said President James W. Parker at the Feb. 13 meeting of the Utah Section. He said further that increased production was not demanded until after Pearl Harbor. The increase in the rate of producing war materials is keeping pace with the rate of production attained eighteen months after the American entry into the first World War. On the

FIRST OF SERIES OF NOON DISCUSSIONS, FEBRUARY 3, INAUGURATED BY A.S.M.E. SAN FRANCISCO SECTION UNDER JOINT SPONSORSHIP OF PROFESSIONAL DIVISION COMMITTEE AND JUNIOR GROUP OF SECTION

(Harold T. Avery, chairman of the San Francisco Section is seated in center; on his right is J. A. Campbell, junior vice-chairman of the local Professional Division Committee. On Mr. Avery's left (to the right in the picture) is William S. Everett, chairman of the Junior Group. On Mr. Everett's left is G. F. Sellers, discussion leader. On blackboard in background is Mr. Sellers' outline of organization setup he recommends for an industrial plant to use to provide adequate protection in the present emergency.)

Courtesy of Cleveland Convention Bureau

AIR VIEW OF DOWNTOWN CLEVELAND

(A.S.M.E. Semi-Annual Meeting, Cleveland, Ohio, June 8–10. See page 319.)

whole, he saw a successful outcome to the defense production program. President Parker's talk was warmly received by the audience who appreciated especially its timeliness.

Priority Materials Substitutes at Western Massachusetts

On Tuesday, Feb. 17, Western Massachusetts Section heard C. F. Scott, assistant to the manager, engineering, Bridgeport Works, General Electric Co., discuss "Substitutes for Priority Materials in War Goods." He covered the list of basic metals, observing that we have a plentiful supply of steel, lead, zinc, and magnesium. However, our copper supply is inadequate, as well as nickel, most of which comes from Canada, where production on this line has not been stepped up materially. However, molybdenum is available in fair quantities. Chromium, tin, and cobalt are unobtainable and the outlook for manganese and tungsten is poor. As for tin, 77 per cent of our supply, formerly from the Dutch East Indies, is cut off, but solder, babbitt, and silver plate can be utilized for substitutes. Heating devices, using copper for the resistance unit, will be out by April, but iron wire may be substituted. Plastics was then discussed as a potential substitute but it was pointed out that its use is limited because of the low breaking temperature. The speaker then went into great detail regarding rubber and tin, stating that in 1941 we used a large tonnage of rubber most of which came from British possessions and the Dutch East Indies, all of which is now curtailed. We are now receiving a much lower tonnage a year and will produce a considerable tonnage of synthetic rubber after the plants have been set up. Regarding synthetic rubber, the speaker emphasized that we have a plentiful supply of basic materials but lack facilities for producing the product. Other plantations yielding crude rubber, namely, in Brazil at the Ford plantation, are still available but their supply is limited.

Juniors Meet With Members in Fire Prevention at West Virginia

The Feb. meeting of the West Virginia Section was held jointly with the Charleston Junior Engineers. The featured speaker, Arthur Dunlap, assistant in charge, process safety department, Carbide and Carbon Chemicals Corporation, South Charleston, W. Va., spoke on "Fire Prevention and Fire-Prevention Principles." The program was further enriched by the showing of a film entitled "The Cause and Prevention and Extinguishing of Oil Fires," information of immediate usefulness.

Summer Management Course at Iowa

THE College of Engineering of the State University of Iowa, Iowa City, Ia., announces that it is again offering a three-week summer course in management, designed primarily for persons in industry "who want comprehensive training in production planning, plant layout, motion and time study, and related subjects." The course will run from June 8 to 26 with well-known managers and industrial engineers conducting lectures.

For complete information, tuition, fees, and living expenses, communications should be addressed to Ralph M. Barnes, 107 Engineering Building, University of Iowa, Iowa City, Iowa.

Advanced Instruction and Research in Mechanics at Brown University

DURING the summer of 1942 and the coming academic year Brown University will continue and expand the Program of Advanced Instruction and Research in Mechanics which was begun in June, 1941, and announced in the June and August issues of MECHANICAL ENGINEERING for 1941. For the summer session (June 15–August 29) 80 persons will be enrolled, of which 20 will be devoting their main attention to research in aeronautics. For the academic year 40 persons will be selected and fellowship funds are available, ranging from \$600 for those completing the undergraduate training to fellowships of postdoctoral size.

An outstanding group of eight men has been secured for the faculty for the summer: S. Bergman, L. N. Brillouin, W. Feller, R. E. von Mises, W. Prager, S. A. Schelkunoff, I. S. Sokolnikoff, and J. D. Tamarkin. The project is supported by the Engineering, Science, and Management Defense Training Program of the United States Office of Education and by grants from the Carnegie Corporation of New York and the Rockefeller Foundation. Further information may be obtained from the Dean of the Graduate School, Brown University, Providence, R. I.

A.S.M.E. Local Sections

Coming Meetings

Anthracite-Lehigh Valley. April 24. Meeting will be held at Scranton, Pa. Subject: "Industrial Demobilization."

Central Indiana. April 10. Indianapolis Athletic Club, Indianapolis, Ind., at 6:30 p.m. Subject: "Owens-Illinois Personnel Program," by F. L. Flood, personnel director, Libby-Owens-Ford Glass Company, Gas City, Ind.

Detroit. April 7. Subject: "Detroit Ordnance Machine Tools," by Christian A. Birkebak, development engineer, and C. R. Alden, chief engineer, Ex-Cell-O Corporation.

Louisville. April 16. University of Louisville, Speed Building at 7:30 p.m. Subject: Film and Talk, "Defense in Dixie," and "Defense and the Telephone," by C. H. Green, Southern Bell Telephone & Telegraph Company.

St. Louis. April 24. Dinner Meeting. Subject: "Work Simplification," by W. V. B. King, process engineer, Western Cartridge Company.

Washington, D. C. April 9. Potomac Electric Power Co. auditorium. Subject: "The Washington National Airport," by John Groves, manager of the Washington National Airport.

Waterbury. April 14. Waterbury Club, Waterbury, Conn. Dinner at 6:30 p.m., meeting at 8:00 p.m. Subject: "Powder Metallurgy," by H. E. Hall, general manager, Metals Disintegrating Company.

With the Student Branches

University of Michigan Student Branch Members Roast Professors

Faculty Members Perspire Under Student Quizzing for the Honor of Winning Coveted Cup at Dinner

THAT fun and merriment are as much a part of the program of A.S.M.E. Student Branches as technical meetings and inspection trips is the belief of MICHIGAN BRANCH which held its eighth annual "Roast" on Dec. 9. Before an enthusiastic crowd of more than 80 members and guests, four professors squirmed and perspired with student-made quiz questions propounded to them by Prof. Axel Marin. Victims included William W. Gilbert, Clarence F. Kessler (the winner), John M. Nickelsen, and John A. Van den Broek.

The Roast grew out of a student-faculty banquet organized in 1928 to promote closer relations between the faculty and students. Prior to 1934, when the Roast was introduced, it was customary to have a speaker on some technical subject or social phase of engineering. The new theme of the meeting was a grilling of the faculty members by the students for sins committed in the classroom. A roastmaster is selected to referee the inquisition. The "spoofuncup," consisting of a tin cup and funnel with large tablespoons for handles, is awarded to the "roastee" who proves himself most capable of taking a "roasting." This award to a popular member of the faculty has become an annual affair looked forward to by the students.

Some of the facts brought out at this last affair were that one of the candidates, who is reputed to lie awake nights thinking of the worst possible moment to "pop" a 10-minute quiz on unsuspecting students, has a girl friend among the Radio City "Rockettes;" another besides being a rhumba artist is also a self-styled golf player and floriculturist extraordinary; a third one who has a sense of humor and keen wit which enables him to keep ahead of his students is rumored to have memorized a copy of "Jokes and Anecdotes for All Occasions;" and the one lanky in build does not permit his extensive consulting practice in National Defense to interrupt those "blue-book" quizzes.

Arizona Cancels Inspections

At the Feb. 5 meeting of ARIZONA BRANCH, the members voted to cancel all inspection trips for the duration of the war because of the difficulty encountered in arranging for such trips. Furthermore, the Branch has decided to hold only one meeting a month instead of two as before. It is felt that more effort could be made for producing a more interesting meeting.

CALIFORNIA BRANCH had more than 70 members and guests at the initial meeting of the semester held Feb. 4. After various announcements, Warren Probst gave a talk on "The Extraordinary Adventures of Patrick B. McGurgle." Following him, Ernie Smith, well-known sports announcer, gave an interesting discourse, sprinkled with lively humor, on the problems of sports announcing. On Feb. 25, Carl Moyes spoke on the use of nonmetallic materials used as bearings, such as Micarta, rubber, and Bakelite.

C.C.N.Y. BRANCH showed two motion pictures on the use and operation of the milling machine and vertical lathe during the Feb. 12 session. The pictures covered the set-up and operation of the machines for certain definite jobs as well as the precautions necessary for the maintenance of required dimensional tolerances. The brief meeting on Feb. 19 featured the sale of Defense Stamps to the members who were present.

COLORADO STATE A.&M. BRANCH turned its meeting of Feb. 16 over to Lee McKittrick, who presented a paper entitled "Lighting and Illumination." The talk proved to be one of the most interesting that has been presented to the Branch this year.

AT EIGHTH ANNUAL "A.S.M.E. ROAST" HELD AT UNIVERSITY OF MICHIGAN UNION

PROF. CLARENCE F. KESSLER RECEIVING THE "SPOOFUNCUP" AT A.S.M.E. ROAST, UNIVERSITY OF MICHIGAN
(In background is Professor Axel Marin who quizzed his colleagues.)

Connecticut Branch Inaugurated

Success was the keynote of the inaugural meeting on Feb. 19 of CONNECTICUT BRANCH, which featured a dinner and an address by James W. Parker, president of the A.S.M.E. Other prominent guests included Clarke Freeman, vice-president, Ernest Hartford, executive assistant secretary, Alton C. Chick, chairman of the Committee on Relations With Colleges, and faculty representatives from Brown University, Rhode Island State College, and Yale University. The general theme of Mr. Parker's address was the task of engineers in effecting the transition from peacetime to wartime production. He mentioned specific examples from the automotive industry and stressed the competence and integrity of men like Knudsen and others who have been assigned the job of seeing that this production is carried out in the most efficient manner during the emergency. The importance of newly graduated engineers to the engineering profession during the present emergency was emphasized.

COOPER UNION BRANCH opened its meeting of Feb. 24 with an appeal by Chairman Murray Sackson to the members to present more papers. Then, Mortimer Mandle gave an illustrated talk on "Bakelite Molding Plastics."

CORNELL BRANCH featured papers by two members at the Feb. 24 meeting. Sherwood Holt gave an interesting talk on aerial photography and A. Francis Binder told about his experiences in a factory manufacturing and testing parachutes.

DELAWARE BRANCH met on Feb. 5. The speaker of the evening was Lloyd M. Church, Carrier Corporation, who spoke on "Recent Developments in Air Conditioning."

FLORIDA BRANCH discussed many business items at the Feb. 20 meeting, including the field day to be held on April 25 at Lake Wau-

PROF. R. W. ANGUS ADDRESSING ON JANUARY 22 COMBINED DINNER MEETING OF TORONTO UNIVERSITY STUDENT BRANCH AND MECHANICAL CLUB OF THE UNIVERSITY WITH JUNIOR GROUP OF A.S.M.E. TORONTO SECTION

burg. Allen Lang was the speaker of the day—his paper being "The Manufacture of Cartridge Cases."

Talk and Movie at Idaho

Meeting on Feb. 18, members of IDAHO BRANCH elected officers for the coming semester. Chairman Jack Curtis took over the meeting and introduced Art Benny, who spoke on the recent developments in research on beryllium-copper. There was also shown a sound motion picture on "How to Run a Lathe."

ILLINOIS TECH showed motion pictures at its February meetings. On Feb. 13, "Steel for the Ages" reviewed the making of stainless steel. The Feb. 27 showing, "Ford's River Rouge Plant," proved very interesting to the 50 members who were present.

KENTUCKY BRANCH called upon one of its members, John W. Carson, to give a talk at the Jan. 23 meeting based on the paper presented by Prof. Charles F. Scott at the 1941 Semi-Annual Meeting of the A.S.M.E. in Kansas City.

Michigan Learns Etiquette

Indications of a new trend toward civilization among engineers took place at the Jan. 22 meeting of MICHIGAN STATE BRANCH when Miss Elizabeth Conrad, dean of women at the College, spoke on "Etiquette and Formal Dancing."

MISSISSIPPI STATE BRANCH devoted its Feb. 5 meeting to papers presented by student members J. L. Powell and L. T. Wade, who related their experiences while working for the Douglas Aircraft Corporation last summer. It was apparent from the talks that the young men had gained very valuable experience during their brief time in industry.

50th Anniversary at Missouri

In celebration of the founding of the department of mechanical engineering at the University fifty years ago, the MISSOURI BRANCH sponsored a dinner on Feb. 20. Speakers included F. A. Middlebush, president of the University, talking on "Engineering Has Come to Stay;" A. L. Westcott, professor emeritus, "The Corliss-Engine Days;" Col. A. McIntyre, head of the University's R.O.T.C., "Mechanical Engineering in a Modern Army;" W. S. Williams, professor emeritus, "Mechanical Transportation Pays for Rails and Roads;" and H. A. Curtis, dean of the college of engineering, "Now It's War—But After That?"

MONTANA STATE BRANCH had two interesting talks at its Feb. 19 session. William McClay described the construction and operation of the College's seismograph and Louis DeFrate discussed "Medieval Torchers."

MISSOURI MINES BRANCH met on Feb. 18 and heard Kenneth Roffman talk on "Radiant Heat." This was followed by a sound film entitled, "Diesel: The Modern Power."

NEBRASKA BRANCH at its meeting of Feb. 4 featured as guest speaker Lieut. Col. Luke Zeck, U. S. Army, who described his experiences in the Philippines, including two years on the Island of Mindanao with the Morros.

NEWARK BRANCH had to dispense with its announced speaker for its Feb. 19 meeting because of the war. However, the Standard Oil Company did send two motion pictures entitled "Design for Power" and "Friction Fighters."

NEW MEXICO BRANCH members compiled a set of questions concerning themselves, copies of which were distributed to each professor to answer. The answers then would be turned over to Dean Farris who would discuss the answers in person with each individual member.

NEW MEXICO STATE BRANCH presented at its Feb. 3 meeting three reels of motion-picture films on oxyacetylene welding. Plans were also made for the St. Patrick's Day party.

N.Y.U. Hears About Rockets

Richard Finke, member of the N.Y.U. BRANCH (aeronautical), addressed the group on

MEMBERS OF THE SENIOR CLASS OF MECHANICAL ENGINEERS AT THE UNIVERSITY OF TEXAS ON THEIR ANNUAL INSPECTION TRIP

(Photograph was taken during a visit to the Lufkin Foundry & Machine Company. On the same trip the group visited Houston where inspection trips were made to the Deepwater Power Plant, the Sinclair Refining Company Plant, the Reed Roller Bit Company, the Hughes Tool Company, the McEvoy Company, the Houston Shipbuilding Corporation, the Texas Electric Steel Casting Company, the Wyatt Metal & Boiler Works, and the air-conditioning equipment in the Esperson Building. Prof. V. L. Doughtie, Mem. A.S.M.E., and R. A. Bacon, Jun. A.S.M.E., were faculty members making the trip.)

A.S.M.E. STUDENT MEMBERS AT MISSOURI SCHOOL OF MINES, FEBRUARY, 1942

jet propulsion for airplanes. The process involved is one which consists essentially of the burning of the fuel at constant pressure and then ejecting the exhaust gases through a nozzle isentropically and at steady flow. Rocket motors cannot possibly hope to compete with present engines as a source of power until aircraft can operate at higher altitudes and greater speeds. It has been shown by tests performed by the N.A.C.A. that for a speed of 100 mph the rocket motor uses approximately ten times as much fuel as a present-day engine. However, at 300 mph, rocket propulsion used but three times as much fuel. Therefore it can be assumed that as greater speeds and altitudes are reached, it will become economical to use jet propulsion for aircraft.

N.Y.U. Branch (mechanical) presented a film on the Tacoma Narrows Bridge collapse at the March 4 session. Running comments were made by Dean William Bryans.

Northeastern Branch learned about the construction and design of machine tools and machine equipment from Adolph Dorosz at the Feb. 10 session. From experience gained with the Vought-Sikorsky Aircraft Company, he explained the problems and methods of toolmaking, and demonstrated the use of the toolmaker's equipment.

Ohio State Student Speakers

At the Feb. 13 and 23 sessions of Ohio State Branch, the following student members presented papers: Allen L. Jones, "The Evolution of Matter;" Charles Melton, "Variable-Pitch Airplane Propellers;" Michael P. Mitro, "The Tragedy of Waste;" Samuel G. Hicks, "Steam Versus Diesel-Electric Locomotives;" Roger W. Biser, "Meteorology;" and Paul W. Recknagle, "How Smooth Should a Bearing Surface Be?"

Oklahoma Branch conducted an interesting meeting on the evening of Feb. 12. Lieut. Comdr. Kowalyck of the Navy R.O.T.C. presented three moving pictures, "The World Today," "Repair, Supply, and Relief," and "Service in Submarines." Lieut. Williams of the Army R.O.T.C. gave a short talk on the functions of engineers of the U. S. Army in the field as well as in the shop. The entertainment for the evening consisted of a xylophone solo by Miss Lahoma Kerr.

Pittsburgh Branch believes in having student speakers at its meetings. On Feb. 5, Robert Parke talked on "Jet Propulsion of Aircraft," John Glasson discussed the results of tests on a Vermiculite compound claimed to increase automobile-engine performance, and George Mitchell described "Mosquito Boats." At the Feb. 19 session, Lewis P. Litzinger outlined the construction and operation of a new type of steel-annealing furnace recently developed and built by the Wean Engineering Corporation.

Pratt Branch at its meeting of Feb. 12 had as speaker C. M. Ripley, General Electric Co. In his paper on "A Kilowatthour," he emphasized the need of power for war transportation.

Queen's Branch Organized

At a meeting of third- and fourth-year students of the mechanical-engineering department at Queen's University, Kingston, Ontario, Canada, held last month, a new A.S.M.E. Student Branch was organized. Officers elected to head Queen's Branch are G. W. Sherk, chairman, J. H. Brazier, vice-chairman, E. W. Parker, secretary, and G. F. W. McCaffrey, treasurer. His first act of office for Chairman Sherk was the appointment of program, dues, and membership-committee members.

Rice Branch had as guest speaker L. L. Cole, Warner & Swasey Co., at its Feb. 25 meeting. He gave an informal talk on turret lathes, their application to mass production, and the factors affecting the permissible speeds, feeds, and depths of cuts in lathe work. Also discussed were the problems of the machine-tool industry at the present and the part of the industry in the war program.

Rose Poly Branch showed as the first part of the program for Feb. 26 a motion picture on the principles of operation of a four-cycle gasoline engine and its component parts. This was followed by a talk by George Boesel on "Designing Cams for an Automatic Screw Machine."

Joint Santa Clara-Stanford Meeting

A joint meeting was held on Jan. 14 at Stanford University by Santa Clara Branch and Stanford Branch. Tom Jones, chairman of the host Branch, greeted the guests and then introduced Bernard Bannon, chairman of the visiting Branch. He discussed the plans that have been proposed for the continuance of all engineering-school curricula during the summer months. The next speaker was Bertram Depew, of Santa Clara, who gave an account of recent fire-prevention methods, particularly with reference to the use of recently designed divided spray nozzles. The talk was illustrated with motion pictures taken by William Foley, also of Santa Clara. Wesley Hillendahl, of Stanford, spoke on the measurement of air-flow velocities and pressures. After the conclusion of the talks, the visitors were taken on a tour of the mechanical-engineering laboratories and shops.

U.S.C. Branch held a meeting on Feb. 10 at which Dean Vivian delivered a talk on "Powdered Metals and Their Application." Members were given an opportunity to ask questions concerning the subject.

Tennessee Branch turned its meeting of Feb. 19 over to J. E. Patten, erection engineer with Westinghouse Elec. & Mfg. Co., who spoke on "Installation Problems and Procedure." Mr. Patten is at present supervising the installation of a new 1500-kw turbogenerator in the University's power plant.

Big Crowds at Texas A.&M.

Big crowds are usual at the meetings of Texas A.&M. Branch. On Feb. 5, at a joint meeting of the Branch and the local chapter of the I.Ae.S., 280 members and 30 guests were present to hear a talk by F. B. Chapman, of the aeronautical-engineering department, on recent developments in American military aircraft. At the Feb. 19 session, more than 200 members and guests attended the session to view a 50-minute motion picture on "Tri-Cone Drilling Bits." The film, which was in technicolor and required a year to produce, concerned itself with the manufacturing methods used in making the bits, and explained many of the problems involved in designing and using drilling bits.

Texas Tech Branch heard as guest speaker on Feb. 2 Captain Bangs, Asst. P.M.S.&T., who talked on "The Training of Selectees." On Feb. 16, the group made an inspection trip to the Lubbock City Light Plant.

Texas Branch discussed much business at its Feb. 9 session. However, the meeting was concluded with an interesting talk on "Mechanical Engineering Problems in the U. S. Navy," presented by Lieut. Comdr. Freidell, professor of naval science and tactics.

Junior Meeting at Toronto

On Jan. 22 the Toronto Branch joined with the Mechanical Club of the University of Toronto to sponsor a combined dinner meeting with the Junior Group of the Ontario Section, A.S.M.E. Approximately 100 members and guests attended the dinner which was held in the Great Hall of Hart House. The group was addressed by Prof. R. W. Angus, who spoke on his experiences at the Annual Meeting of the Society held in New York in December. He stressed the necessity of collaboration between American and Canadian engineers and pointed out the wonderful opportunities afforded to members of the A.S.M.E. in this connection. After the adjournment of the dinner, the students were guests of the Junior Group at its monthly meeting. Dr. William

Horn, plant superintendent and director of research at the Port Hope radium-extraction plant of Eldorado Mines, spoke on the extraction and characteristics of radium and uranium.

TUFTS BRANCH members made an inspection trip on Feb. 12 through the Somerville plant of the Ford Motor Company. On Feb. 16, three motion pictures were featured which covered high-speed studies of tools on milling, broaching, planing, and punch-press operations.

VERMONT BRANCH discussed various items of business at its Feb. 7 meeting. The members approved the presentation in the future of three or four papers at each meeting by students.

131 Attend Villanova Session

On Feb. 23, William Elmer, a graduate of the school, presented a sound motion picture on the construction of Riley steam-generating units. Besides the 39 members of VILLANOVA BRANCH present, there were guests from the local chapters of the A.S.C.E., A.I.Ch.E., and A.I.E.E., numbering 92.

WASHINGTON STATE BRANCH after concluding the election of officers at the Jan. 22 session, closed the meeting with the showing of a movie on "Highways."

WORCESTER BRANCH's meeting on Feb. 9 was held jointly with the I.Ae.S. A film, "Wright Builds for Air Supremacy," was shown. Following that, John B. Wright, Gene Larrabbee, Harold Crane, and Wilber Day presented papers.

President Parker Welcomed by Wyoming

James W. Parker, President of the A.S.M.E., was the guest of honor and main speaker at the annual student-faculty engineering banquet sponsored by WYOMING BRANCH on Feb. 12. More than 100 members and guests were present for the occasion. Mr. Parker's address was entitled, "A Fork in the Road." After a lengthy discussion of the subject, the Branch presented to him a miniature desk anvil with WYO engraved upon it.

YALE BRANCH met jointly with the New Haven Section, A.S.M.E., on Feb. 24. The speakers of the evening were student members and included: R. I. Bonsal, "Stop Motions for Spinning Machinery," J. P. Josephs, "Fatigue Failures Under Repeated Stress," and J. T. McCready, "A Senior's Views—Past and Future." The talks were well received and a good time was had by all. Coffee and doughnuts completed the meeting.

Technical Periodicals in Russian to Be Listed

THE Science-Technology group of the national Special Libraries Association has undertaken to compile, for the benefit of users of the Russian scientific and technical periodicals, current and otherwise, a complete list of the holdings of such periodicals in all the libraries of the United States and Canada as far as possible, whether personal, institutional, or industrial. Owners and librarians in charge of such materials are asked to co-operate by sending a detailed statement of their holdings to Miss Nathalie D. Frank, 512 West 162nd St., New York, N. Y. Please state also whether the journal can be borrowed on inter-library loan and whether the library has facilities for photostating or microfilming.

Correction to

A.S.M.E. Research Report —Part 1, Fluid Meters

Their Theory and Application (1937)

THE attention of the A.S.M.E. Special Research Committee on Fluid Meters has been called to several typographical errors in the 1937 edition of its research report—Part 1, Fluid Meters, Their Theory and Application. These errors are:

(1) Page 50, Equation [103(*a*)] should read

$$q_c' \text{ (cfh)} = 7827\ KY_1D_2^2 \sqrt{\frac{b_w' p_1 y}{T_1 G}}$$

(2) Fig 59 (pocket figure), on the lower segment of the curve for ρ, the density, the vertical arrow should point down.

Those who have copies of this research publication in their files are requested to make the necessary corrections.

E.C.P.D. Guidance Booklet Now Ready

A NEW vocational-guidance booklet on engineering, intended for the use of high-school students and their advisers, has just been published by the Engineers' Council for Professional Development, joint agency of eight national engineering organizations. The booklet entitled "Engineering as a Career" is planned to help students decide whether they are fitted to be engineers, by giving them a general picture of the characteristics and requirements common to all branches of the profession and discussing the qualities and aptitudes needed by engineers.

In the first section, "The Scope of Engineering," are included discussions of what engineering is and what engineers do, the functions of engineering, the "engineering method," as well as answers to the question "who should study engineering?" an outline of the necessary preparation for such a career, and a survey of probable opportunities and earnings. The second section presents more detailed accounts of the activities of engineers in the various branches of the profession. The interrelationships among various types of engineering are stressed, and consideration given to the use of engineering training in other fields of activity.

"Engineering as a Career" is intended to give the high-school student, in language that he can understand, the facts he needs to help him choose his career. A list of vocational-guidance books and pamphlets, also primarily concerned with engineering and related vocations, is included. Copies of the booklet may be obtained from Engineers' Council for Professional Development, 29 West 39th Street, New York, N. Y., at ten cents each; discount on quantity orders.

Procedure for Lincoln Prize Papers on War Production Subjects

PROCEDURE for handling papers on war subjects for submission to the James F. Lincoln Arc Welding Foundation in the $200,000 Industrial Progress Award Program has been announced by the officials of the Foundation. In making the announcement, the Foundation expressed the belief that many persons whose work is involved in the war effort and whose choice of subject matter for papers is limited to war equipment, may be missing participation whereas they might be enabled to participate by following the procedure suggested.

The many persons engaged in war industry production may be sure that their work is covered in one of the 46 divisions of participation of the Progress Program. If the proper division is not immediately apparent to the person interested in participating by preparation of a paper on some item of war equipment, he may obtain the necessary information by writing the Foundation.

Since the Progress Program closes June 1, it was pointed out by the Foundation that all persons should take the suggested steps immediately in order to clear the way for their participation. No one should conclude that a subject related to war production is not admissible until officially and finally so designated by the proper bureau of the Army or Navy. The procedure for securing a decision on the admissibility of a given subject may be obtained by writing to the James F. Lincoln Arc Welding Foundation, Cleveland, Ohio.

Lamme Medal Awarded to Forrest E. Ricketts

THE 1941 Lamme Medal of the American Institute of Electrical Engineers has been awarded to Forrest E. Ricketts, vice-president, Consolidated Gas Electric Light and Power Company, Baltimore, Md., "for his contribution to the high reliability of power-supply systems, especially in the design of apparatus for selective relaying and circuit reclosure." The medal and certificate will be presented to him at the annual Summer Convention of the Institute, which is to be held in Chicago, June 22–26, 1942.

The Lamme Medal was founded as a result of a bequest of the late Benjamin G. Lamme, chief engineer of the Westinghouse Electric & Manufacturing Company, who died on July 8, 1924, to provide for the award by the Institute of a gold medal (together with a bronze replica thereof) annually to a member of the American Institute of Electrical Engineers, "who has shown meritorious achievement in the development of electrical apparatus or machinery" and for the award of two such medals in some years if the accumulation from the funds warrants. A committee composed of nine members of the Institute awards the medal.

(*A.S.M.E. News continued on page 330*)


THE DANGER LIES AT THE TURNS
Acme Photo

Engineering Societies Personnel Service, Inc.

These items are from information furnished by the Engineering Societies Personnel Service, Inc., which is under the joint management of the national societies of Civil, Electrical, Mechanical, and Mining and Metallurgical Engineers. This Service is available to members and is operated on a co-operative, nonprofit basis. In applying for positions advertised by the Service, the applicant agrees, if actually placed in a position through the Service as a result of an advertisement, to pay a placement fee in accordance with the rates as listed by the Service. These rates have been established in order to maintain an efficient, nonprofit personnel service and are available upon request. This also applies to registrants whose notices are placed in these columns. All replies should be addressed to the key numbers indicated and mailed to the New York office. A weekly bulletin of engineering positions open is available to members of the co-operating societies at a subscription of $3 per quarter or $10 per annum, payable in advance.

New York	Chicago	Detroit	San Francisco
29 W. 39th St.	211 West Wacker Drive	100 Farnsworth Ave.	57 Post Street

MEN AVAILABLE[1]

MECHANICAL ENGINEER, 33, married. Post-graduate studies, management. Fifteen years' industry experience, supervision, liaison. Writer, speaker, sales personality. Now training in time study, production methods, for management connection. Me-741.

INDUSTRIAL ENGINEER, 59, wide experience, including superintendent, general manager, and director in several corporations engaged in machinery manufacture. Supervised all plant operations, including executive departments. Prefer western New York or Middle West. Now employed. Me-742.

MECHANICAL ENGINEER, 40, desires responsible position in research, development, or sales-engineering department. Fifteen years' diversified mechanical experience including time study, design, cost reduction, experimental testing, stress analysis and pipe fabrication. Will travel some. Good draftsman. Want permanent future. Me-743.

PLANT ENGINEER, 50, now employed in radio industry. Experience in design, maintenance; power-plant engineer. Fully qualified to discharge engineering and executive duties. New Jersey license. Me-744.

MECHANICAL ENGINEER, 20 years' responsible charge in steam power, heating, refrigeration, water supply, and sewage. Now employed as municipal consultant. Available for full or part-time work; licensed professional engineer. Me-745.

MECHANICAL ENGINEER, 23, desires placement with progressive firm. Apprenticed machinist and engine mechanic; full of ideas and creativeness. Varied factory and engineering experience in addition to teaching, writing, and administration. Loves to get dirty. Me-746.

GRADUATE MECHANICAL ENGINEER, 25, single, with design experience on automatic machinery, material handling, structural steel, concrete, piping, and chemical-plant layout. Executive potentialities. East or Middle West preferred. Me-727.

[1] All men listed hold some form of A.S.M.E. membership.

POSITIONS AVAILABLE

PLANT SUPERINTENDENT, 40–50, with about 15 to 20 years' experience in machine-tool operations in copper, brass, and bronze interchangeable parts. Must be capable labor supervisor. Prefer man now employed. Must be citizen of United States. Permanent. Salary, about $7500 year. Northern New Jersey. Y-9975.

GRADUATE INDUSTRIAL ENGINEER with 3 or 4 years' practical experience in time-study work of plant similar to that of manufacturers of electric coils for motors and generators. Either Middle West or South. Y-9995-D.

PLANT SUPERINTENDENT to supervise small plant manufacturing surgical and dental instruments. Must understand stamping, forging, and machining of all grades of stainless steel. Will be required to estimate cost and production time as well as supervise labor. Permanent. Salary, about $3600 year. New York, N. Y. W-1.

MECHANICAL ENGINEER for development work in plant-engineering department. Should have 5 or more years' experience in industry or industrial processes. Should have thorough knowledge of thermodynamics, combustion problems, heat-transfer, some machine-design and material-handling methods. Work will be investigation and planning improvement methods in processing and production with their possible economic advantages for any changes recommended. Must be able to compute and evaluate changes recommended, justify any changes in processing and methods he may recommend, and accordingly be able to compute financial return to be obtained from any additional investment required. Pennsylvania. W-3.

RECENT GRADUATE MECHANICAL ENGINEER, 22–28, to act as assistant to plant-welding engineer. Must have been graduated from recognized technical school with B.S. degree and have had either some undergraduate work in welding or some practical experience since graduation. Must be U. S. citizen. $2000 year. Pennsylvania. W-15.

HEAT TRANSFER ENGINEER to do estimating and design on heat exchangers, plus some research in field. Should have some experience in either heat-exchanger manufacture or large industrial plant using heat exchangers in process work. Will be assistant to manager of division. $3000–$3300 year. Permanent. Pennsylvania. W-17.

ASSISTANT NEW WORKS ENGINEER, about 30, mechanical or chemical engineer, graduate, to act as understudy for plant or new works engineer. Will be responsible for co-ordinating new work for large chemical-processing company. $3600–$4200 year. New Jersey. W-25.

MASTER MECHANIC, mechanical graduate preferred, not over 45, for general plant maintenance including chemical process equipment, packaging and materials handling, electrical and steam generation. Should have about 10 years' experience in supervisory capacity. $4000–$5000 year. Location, New Jersey. W-26.

DEVELOPMENT ENGINEER, graduate mechanical, for development work in connection with liquid-flow equipment. Must have background in theory of flow through orifices and venturies, also jets and nozzles. Must be able to apply horse sense to ideas and eliminate unsound theories. Good design background in hydraulic equipment desirable. Permanent. $4000 year. New Jersey. W-28.

PURCHASING ENGINEER, specialized in machinery, tools, and equipment for mining and railroad companies. Mechanical or mining engineer preferred. Certain knowledge of French an asset. New York, N. Y. W-40.

MECHANICAL ENGINEER, 35–40, maximum; designer and field engineer for industrial building construction. Will be expected to carry on designs and calculations under chief design engineer and field construction under construction superintendent. Must have car. Salary to $3900 a year. Headquarters, either New York or Connecticut. W-46.

SUPERINTENDENT OF PRODUCTION for marine triple-expansion-engine plant. $6000–$10,000 year. New York State. W-47.

DEVELOPMENT ENGINEERS for long-time employment on development of variety of old and new products in organized department of large established manufacturer of power-plant equipment. High academic standing required; experience in either manufacturing, design, drafting, or previous development work desirable. American citizenship and birth imperative. Pennsylvania. W-51.

MATERIAL CONTACT MAN, either chemical or mechanical engineer, to work between process, engineering, and purchasing departments. Should be familiar with handling of liquid chemicals and be able to specify materials for pumps, piping, valves, etc., which would be resistant to chemical action. Also able to judge adaptabilities of such materials to use in question. Should have some knowledge of purchasing procedure. Junior, $3000–$4200 year; senior, $4200–$7200 year. West. W-57-D795.

LUBRICATION ENGINEER, graduate mechanical, experienced in engine lubrication for study and recommendation of lubrication for extreme engine speeds, etc. Previous experience in research laboratory of outstanding oil company desirable. $3900–$4500 year. New Jersey. W-58.

MECHANICAL ENGINEER, 35–50, to head all

(*A.S.M.E. News continued on page 332*)

engineering for new large bomb-loading plant. Will be in charge of installation of all mechanical equipment, including low-pressure power plant, necessary changes in design, conveyer equipment, etc. After construction, will be made chief plant engineer. Also need assistant mechanical engineer. Salary, $8000–$10,000 year. Southwest. W-63-C.

CHIEF ENGINEER, mechanical, who thoroughly understands machine design and has good working knowledge of steel plate fabrication, particularly as applied to pressure vessels and process kettles. Will take charge of all engineering, supervise all design on special-customer problems, act as liaison between sales department and plant. $7,500–$10,000 year. Southeastern Ohio. W-65.

MECHANICAL ENGINEER, graduate, 40–50, to head equipment development department for large machinery. Company wishes to develop further products, using its large machine plant facilities. $8000–$10,000 year. New England. W-79.

ENGINEERS. (a) Manufacturing superintendent for machine company manufacturing automotive products, screw machines, and light metal stampings. (b) Supervisor of production for centerless-grinding department. Previous experience essential. (c) Tool designers experienced in layout of tools, dies, jigs, and fixtures for above. Salary open. New England. W-81.

DESIGNERS, DRAFTSMEN, AND LAYOUT MEN for development department of company going into production of small motors, generators, voltage regulators, and other electrical control equipment. Present problem is engineering of product. Later openings in producing phase of work available to applicants. Permanent. Salary open. Middle West. W-92-CD.

GENERAL SUPERINTENDENT, production manager, to take over operation of three plants, two of which are new and are just starting on production. Company manufactures tanks, Diesel engines, bombs, and shells. Salary open. Western Pennsylvania. W-111.

TECHNICAL DEVELOPMENT ENGINEER to redesign and develop entire line of small compressors. Past experience in this line necessary. Permanent. $6000–$10,000 year. New York metropolitan area. W-112.

ASSISTANT SUPERINTENDENT with 7 to 10 years' experience in production field; must be capable of going into shop and showing men how to set up work properly. Opportunity for advancement. Salary open. Connecticut. W-116.

FACTORY SUPERINTENDENT for manufacturer of high-precision gears. Should be thoroughly experienced in specification, installation, and operation of machine tools, particularly those used in machining and manufacture of gears. New Jersey. W-144.

ASSISTANT WORKS MANAGER for large shell-loading plant. Must have previous managerial experience in chemical-production plant. $10,000 year. Middle West. W-145-CD.

Candidates for Membership and Transfer in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after April 25, 1942, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Any member who has either comments or objections should write to the secretary of The American Society of Mechanical Engineers immediately.

KEY TO ABBREVIATIONS

Re = Re-election; Rt = Reinstatement; Rt & T = Reinstatement and Transfer to Member.

NEW APPLICATIONS

For Member, Associate, or Junior

BENEDICTUS, ANDREW R., New York, N. Y.
BRADBURY, GILBERT V., Kansas City, Mo.
BROWN, NORMAN, Woonsocket, R. I.
BURKE, HENRY, St. Louis, Mo.
BUSH, WILLIAM W., Belleville, N. J.
CHADWICK, JOS. J., Akron, Ohio (Rt & T)
COHEN, ROBT., Lincoln, Neb.
COLLINS, DWIGHT R., Denver, Colo.
CORCORAN, JAMES L., Bridgeport, Conn.
COUTINHO, JOHN DE S., Farmingdale, N. Y.
FULLING, ROGER WM., Wilmington, Del.
FULTON, GARLAND, Philadelphia, Pa.
GOLDMAN, JOSHUA, Hadlyme, Conn.
GONGWER, BURR F., Scarsdale, N. Y.
GORDON, ALLAN P., Washington, D. C.
HARTMAN, JAS. B., Easton, Pa.
HARWICK, HARRY K., Lansdowne, Pa.
HENDERSON, FREDK. R., Boston, Mass.
HENSEL, FRANK G., Morrisville, Pa.
HIGGINS, BRADLEY C., Worcester, Mass.
HYLER, LOIELL L., Peoria, Ill.
JORDRE, WM. S., Cincinnati, Ohio
KEGARISE, RALPH R., Marion, Ill.
LAZAN, BENJ. J., State College, Pa.
LEINART, BYRON H., Knoxville, Tenn. (Rt)
LICHTENBERG, EDW. N., New York, N. Y.
LINDENMUTH, DONALD C., Detroit, Mich.
MCCONATHY, DONALD R., New Haven, Conn.
MCCOY, VERL E., Chicago, Ill. (Rt)
MCKINTY, JAMES, New York, N. Y. (Rt).
MCNAUGHTON, STEWART, Philadelphia, Pa.
MICHETTI, ALBERT L., Baltimore, Md.
NAGLE, MARCH E., Chicago Heights, Ill.
PLACEK, EARL W., Seattle, Wash. (Re)
POTTS, MATTHEW W., New Rochelle, N. Y. (Rt)
PRATT, ORVILLE, Omaha, Nebr.
RUNDELL, HARWOOD F., Jackson, Mich.
SCHULTE, WM. C., Highland Park, N. J.
SCHUMO, ELMER M., Hamburg, Pa.
SEVIER, HORACE A., Baltimore, Md.
SPINK, LELAND K., Foxboro, Mass.
TISCH, FRANK P., Oak Park, Ill.
TREBES, HAROLD H., Snyder, N. Y.
TYRRELL, CECIL C., Flushing, N. Y.
WAITE, HOWARD, Los Angeles, Calif.
WHITENER, ERNEST K., Gastonia, N. C. (Rt)

CHANGE OF GRADING

Transfer to Member

AGRONIN, TANY, Middletown, Ohio
CROSBY, GEO. F., JR., Westfield, N. J.
HACKETT, ROBERT S., Scarsdale, N. Y.
MARTIN, JOHN L., West Allis, Wis.
WILKENFELDT, JOHN W., Brooklyn, N. Y.

A.S.M.E. Transactions for March, 1942

THE March, 1942, issue of the Transactions of the A.S.M.E., which is the *Journal of Applied Mechanics*, contains:

TECHNICAL PAPERS

- Effect of Variable Viscosity on Boundary Layers, With a Discussion of Drag Measurements, by J. G. Brainerd and H. W. Emmons
- Buckling of the Circular Plate Beyond the Critical Thrust, by K. O. Friedrichs and J. J. Stoker
- A Short-Gage-Length Extensometer and Its Application to the Study of Crankshaft Stresses, by C. W. Gadd and T. C. Van Degrift
- Measurement of Latent Heat by the Gas-Current Method, by J. A. Goff and J. B. Hunter
- Note on Plane Strain, by W. R. Osgood
- Determining Critical States of Equilibrium of Plates and Shells Under Initial Stress, by H. Hencky
- The Mechanism of Cavitation Erosion, by T. C. Poulter

DESIGN DATA

- Expansion of Formulas for Calculating Loads, Rotation, and Deflections of Quarter Bends and Tangents of Pipes, by A. S. McCormick

DISCUSSION

- On previously published papers by J. T. Burwell, J. Kaye, D. W. van Nymegen, and D. A. Morgan; Ross Gunn; A. Nádai and M. J. Manjoine; N. M. Newmark; E. H. Hull

BOOK REVIEWS

Necrology

THE deaths of the following members have recently been reported to headquarters:

BOLTON, REGINALD P., February 18, 1942
FERGUSON, HUGH M., February 7, 1942
FLEMING, THOMAS, JR., December 3, 1941
ILER, HENRY H., February 4, 1942
JURGENS, EMIL G., May 6, 1941
LUCAS, HENRY M., March 4, 1942
MICKLE, ROBERT T., February 23, 1942
MILSON, THOMAS H., August 18, 1941
NICHOLLS, PERCY, February 12, 1942
OHLE, ERNEST L., February 15, 1942
VANDERBILT, CORNELIUS, March 1, 1942